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Siegel et al.

(10) **Patent No.: US 9,677,772 B2**
(45) **Date of Patent: Jun. 13, 2017**

(54) **INTELLIGENT VENTILATING SAFETY RANGE HOOD CONTROL SYSTEM**

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(73) Assignee: **Rain Mountain, LLC**, Rochester, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 689 days.

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(51) **Int. Cl.**
F24C 15/20 (2006.01)
F24F 7/00 (2006.01)

(52) **U.S. Cl.**
CPC ***F24C 15/2021*** (2013.01)

(58) **Field of Classification Search**
CPC F24C 15/2021; F23L 17/005
USPC .... 126/299 R; 454/61
See application file for complete search history.

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(Continued)

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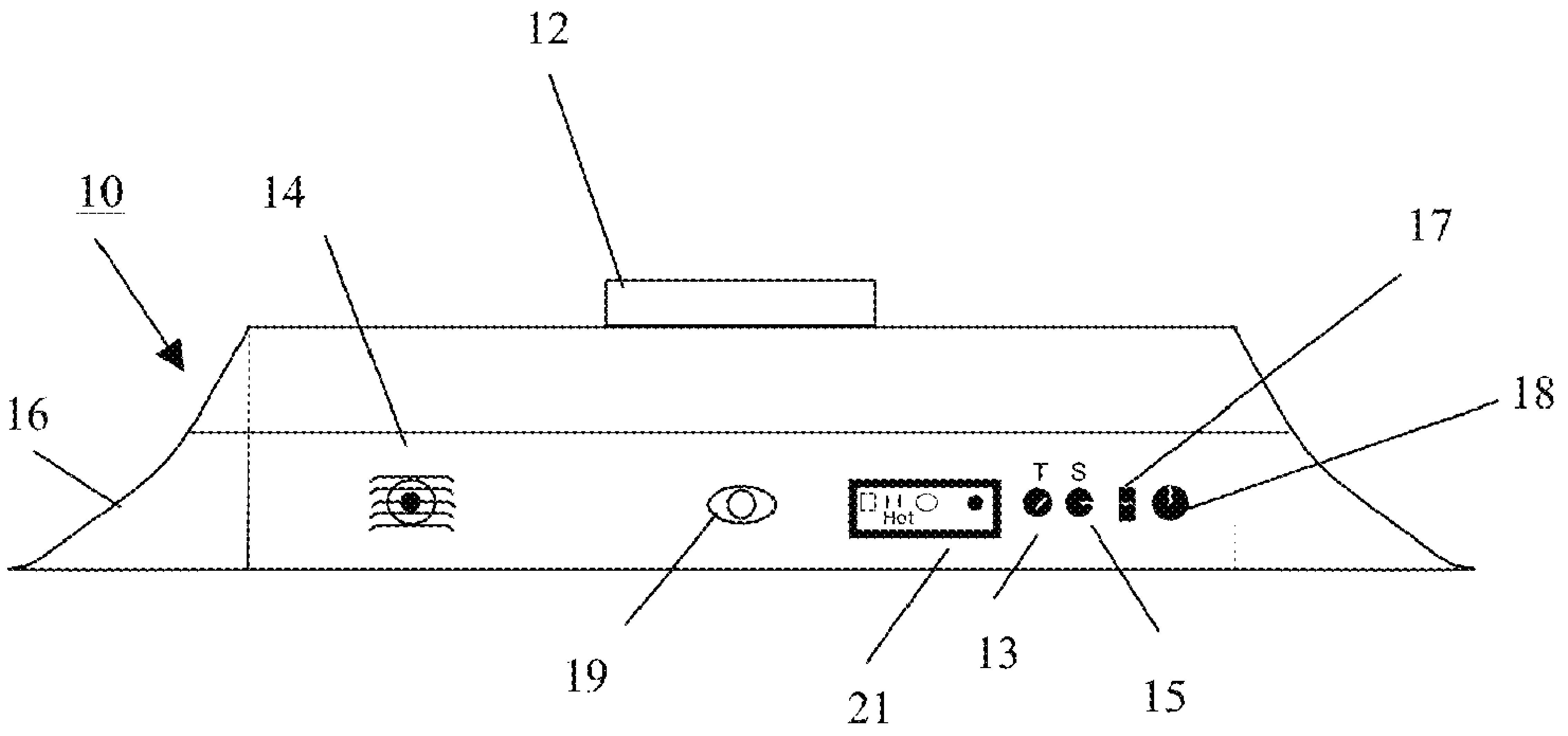
(57) **ABSTRACT**

An improved control system for a range hood that is capable of automatically responding to various air quality parameters including heat, smoke, carbon monoxide, humidity, and others. The system contains a number of features that, combining aspects of open-loop and closed loop control, manage the system dynamics for smoother operation, respond to both level and rate signals and compensate for background conditions and sensor variability by using relative values.

17 Claims, 19 Drawing Sheets



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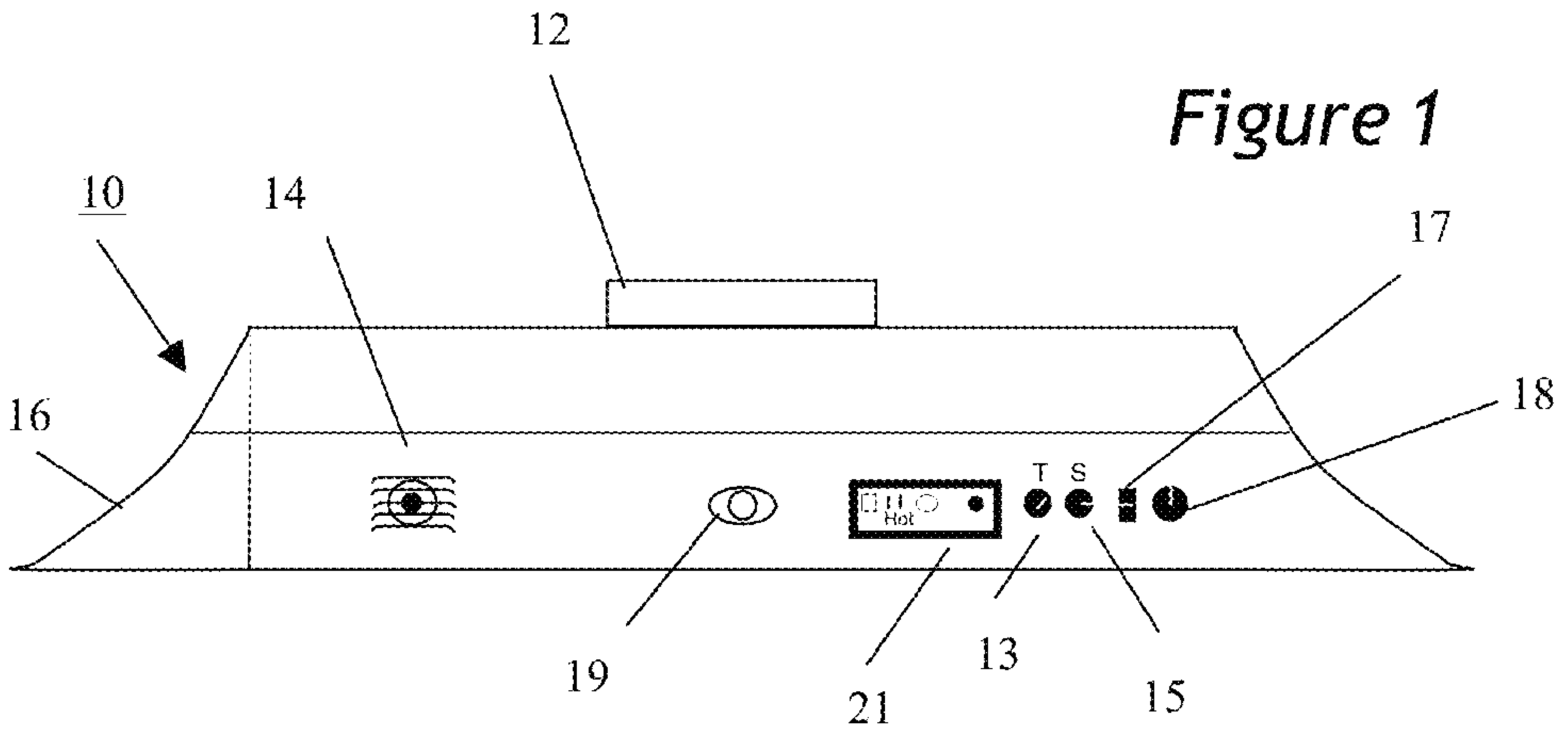


Figure 1

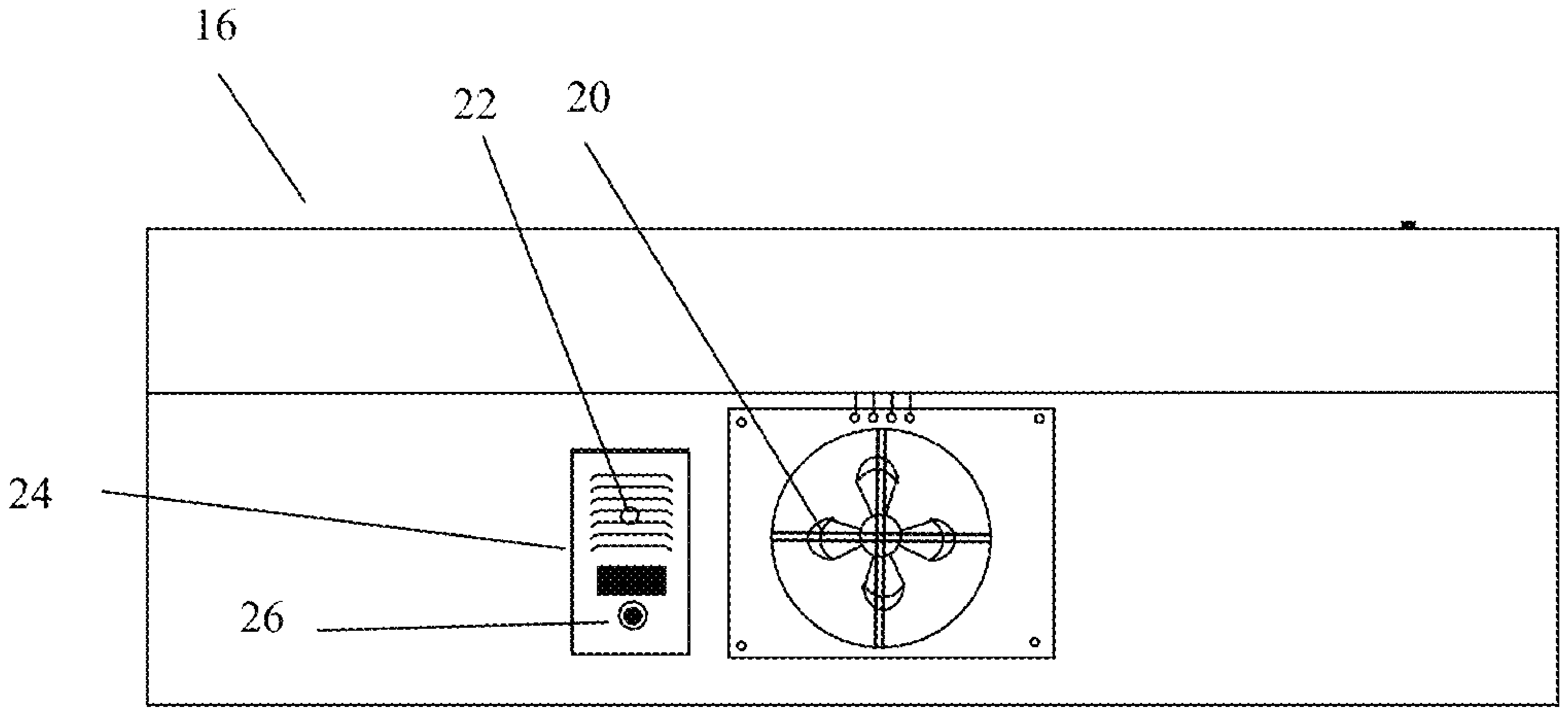


Figure 2

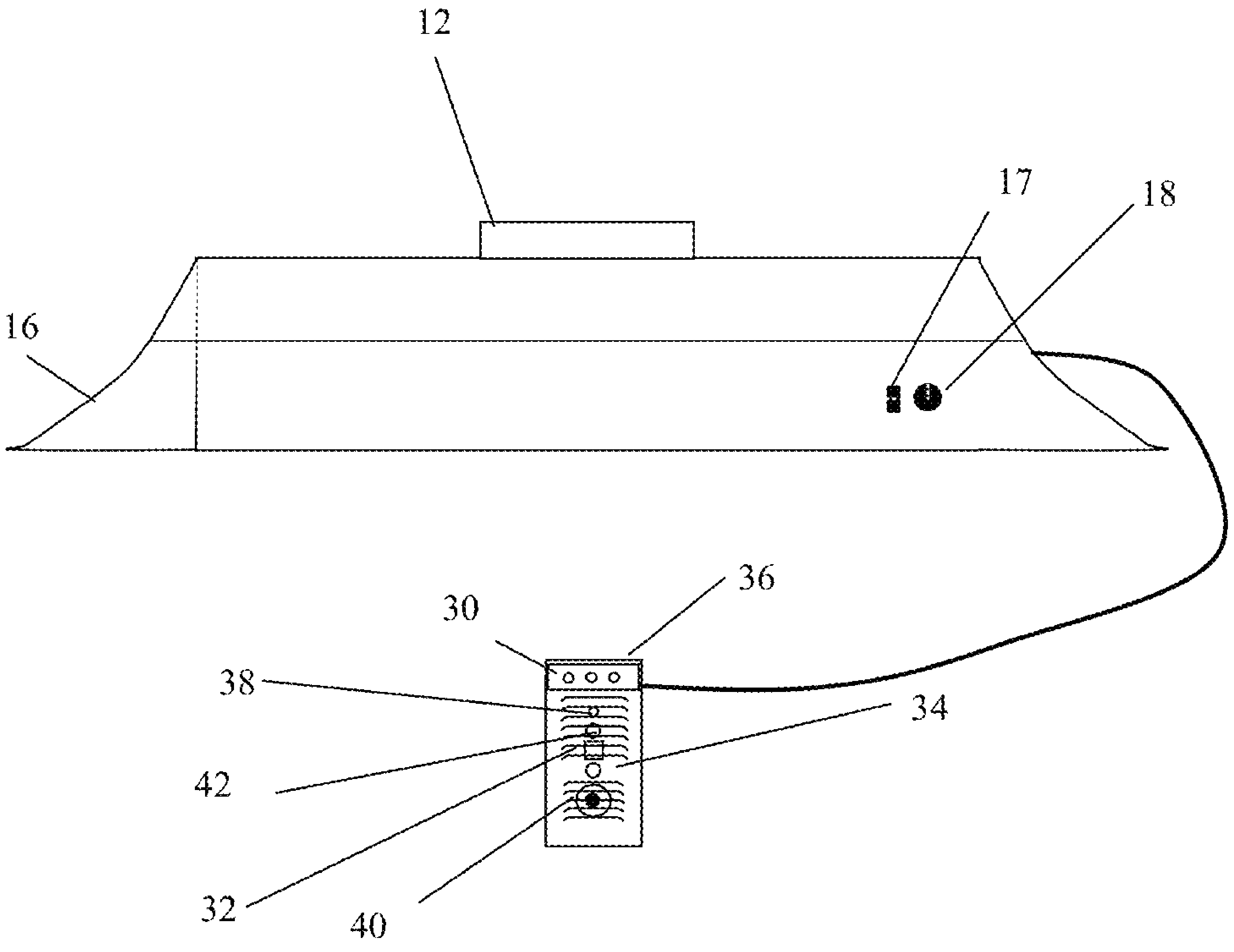


Figure 3

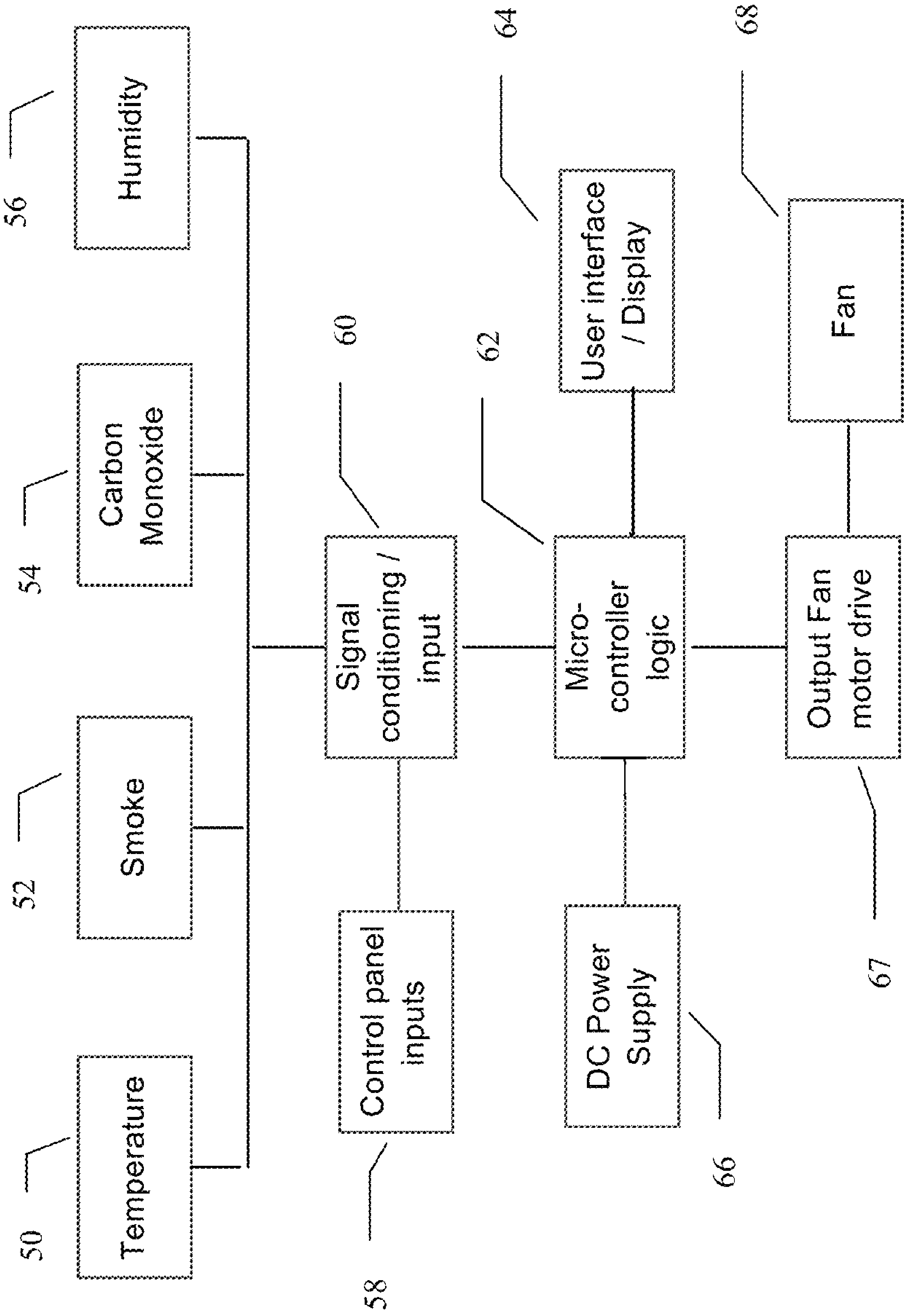
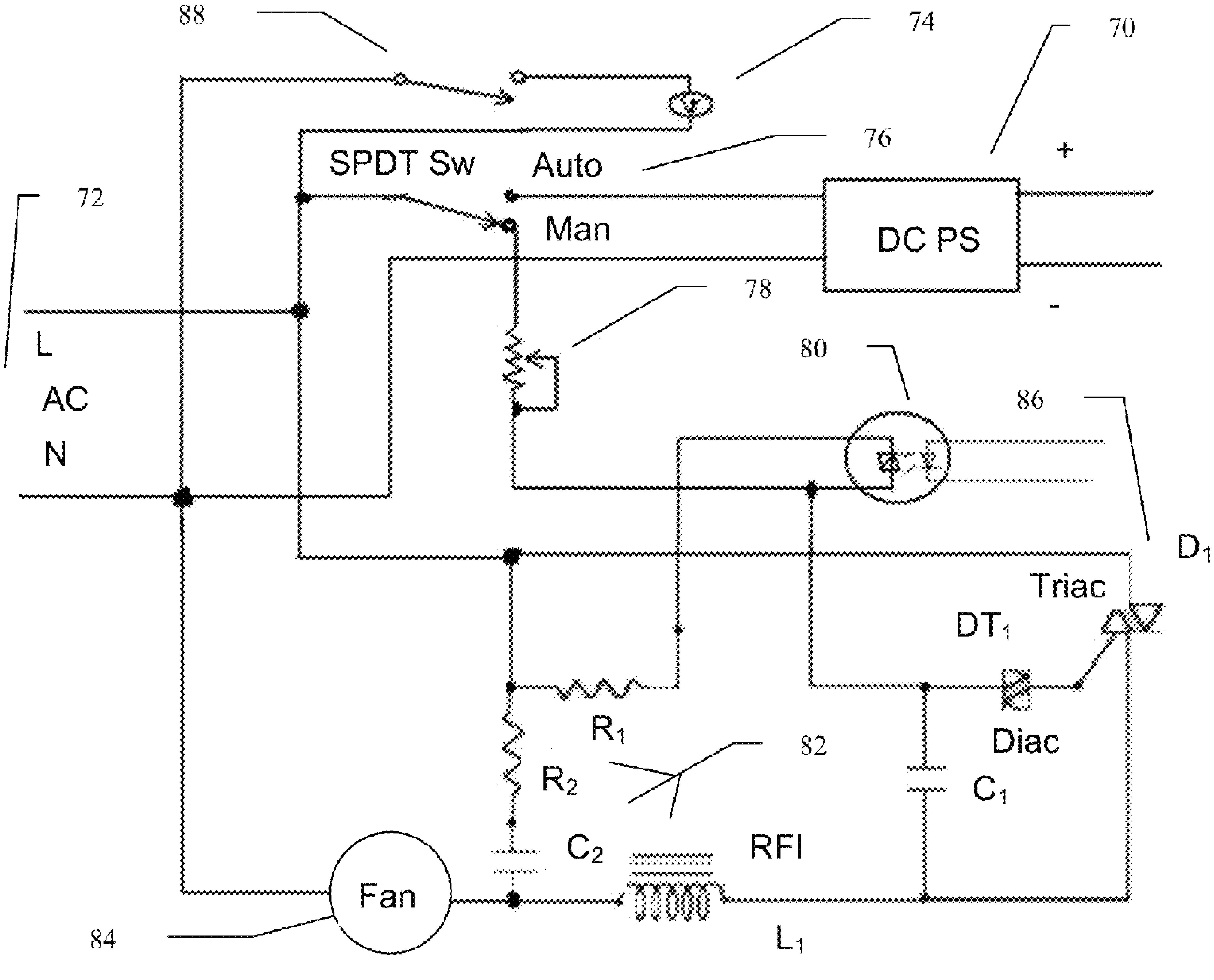

Temperature
50
Smoke
52
Carbon Monoxide
54
Humidity
56
Control panel inputs
58
Signal conditioning / input
60
Micro-controller logic
62
User interface / Display
64
DC Power Supply
66
Output Fan motor drive
67
Fan
68

Figure 4


88
74
70
76
SPDT Sw
Auto
+
72
Man
DC PS
78
-
L
AC
N
80
86
D$_1$
Triac
DT$_1$
R$_1$
Diac
82
R$_2$
C$_1$
C$_2$
RFI
Fan
84
L$_1$

C$_2$

Figure 5

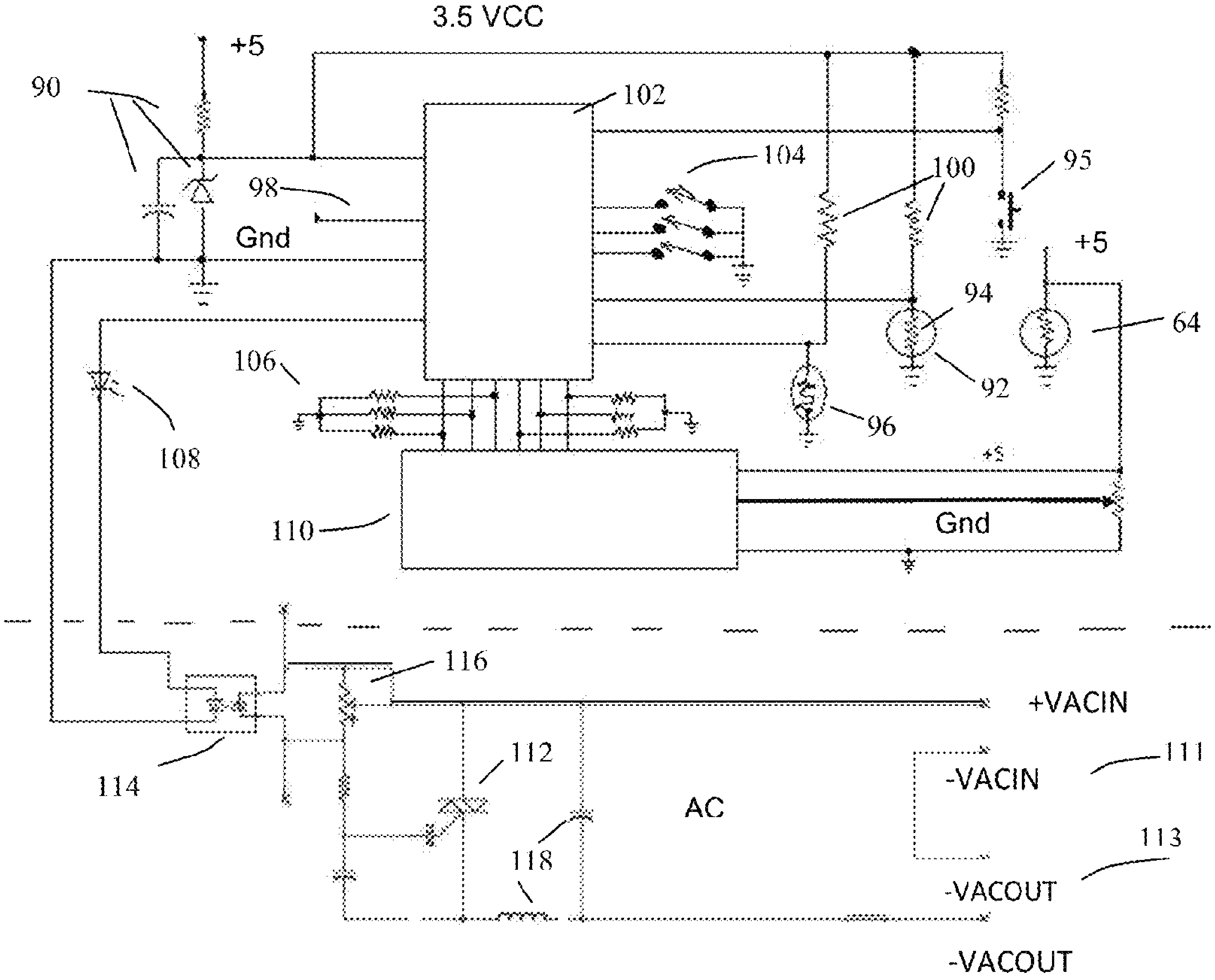

3.5 VCC
+5
90
102
98
Gnd
104
100
95
+5
94
64
92
96
106
108
+5
Gnd
110
116
+VACIN
114
112
-VACIN
111
AC
118
113
-VACOUT
-VACOUT

Figure 6

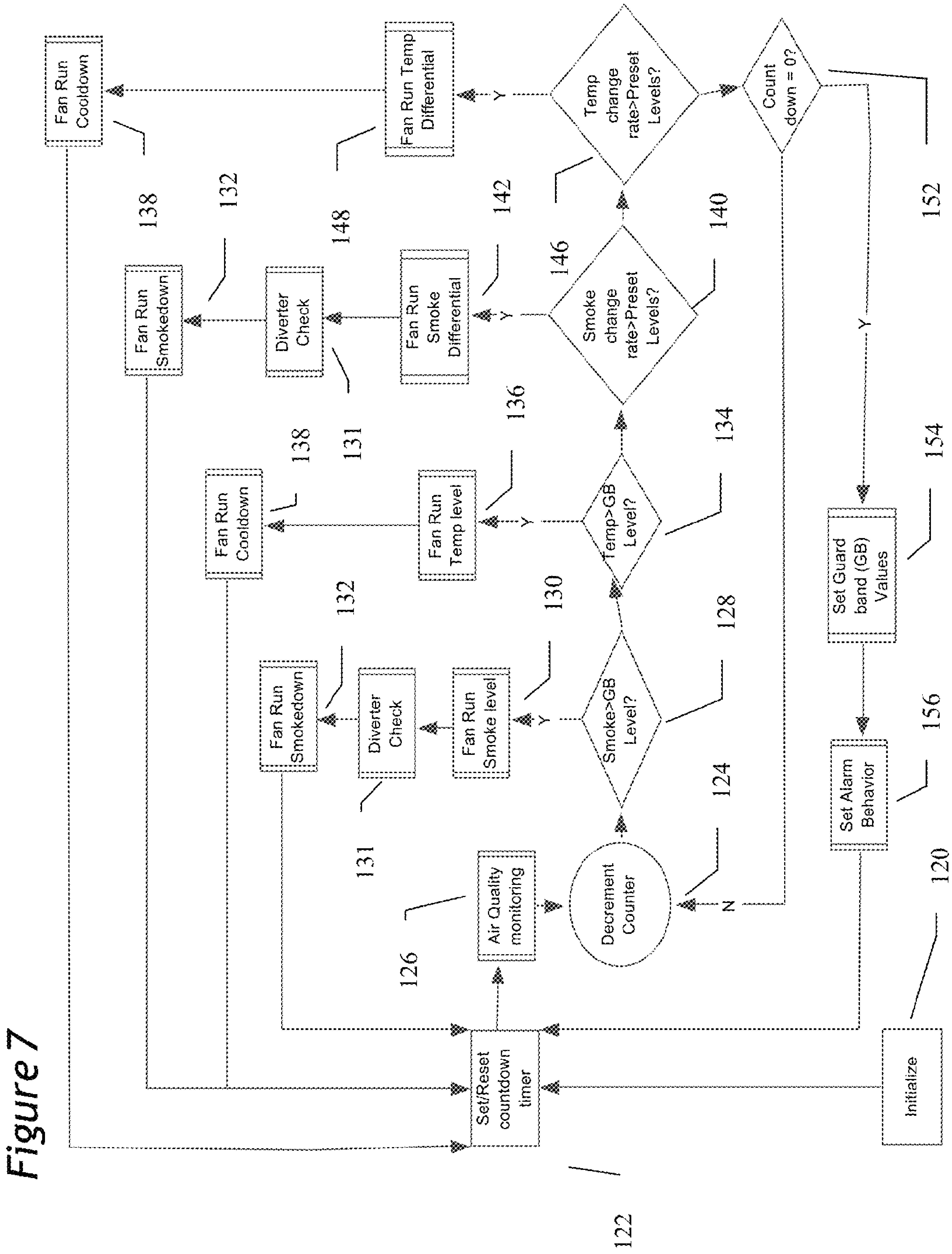


Figure 7
Initialize
120
Set/Reset countdown timer
122
Air Quality monitoring
126
Decrement Counter
124
N
Smoke>GB Level?
128
Y
Fan Run Smoke level
130
Diverter Check
131
Fan Run Smokedown
132
Temp>GB Level?
134
Y
Fan Run Temp level
136
Fan Run Cooldown
138
Smoke change rate>Preset Levels?
140
Y
Fan Run Smoke Differential
142
Diverter Check
131
Fan Run Smokedown
132
Temp change rate>Preset Levels?
146
Y
Fan Run Temp Differential
148
Fan Run Cooldown
138
Count down = 0?
152
Y
Set Guard band (GB) Values
154
Set Alarm Behavior
156

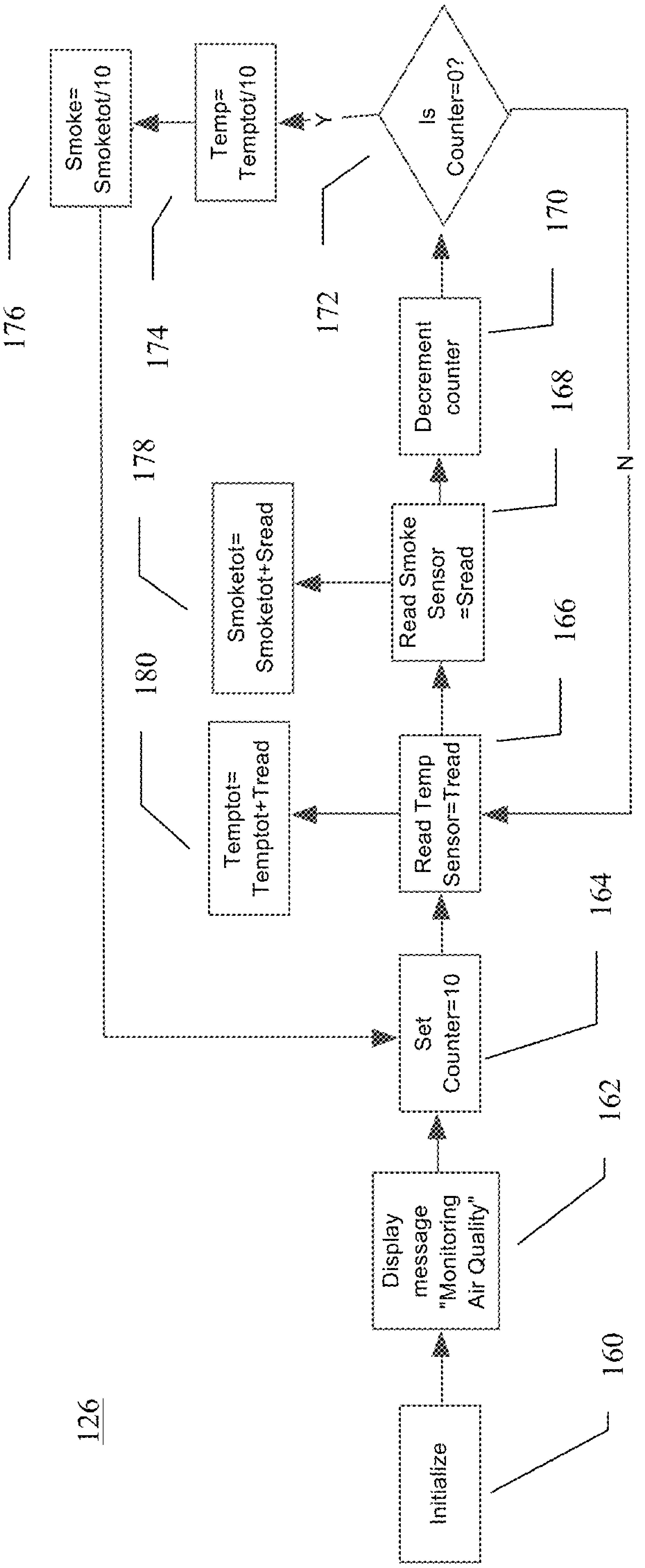

126
Initialize
160
Display message "Monitoring Air Quality"
162
Set Counter=10
164
Read Temp Sensor=Tread
166
Temptot= Temptot+Tread
180
Read Smoke Sensor =Sread
168
Smoketot= Smoketot+Sread
178
Decrement counter
170
Is Counter=0?
172
N
Y
Temp= Temptot/10
174
Smoke= Smoketot/10
176

Figure 8

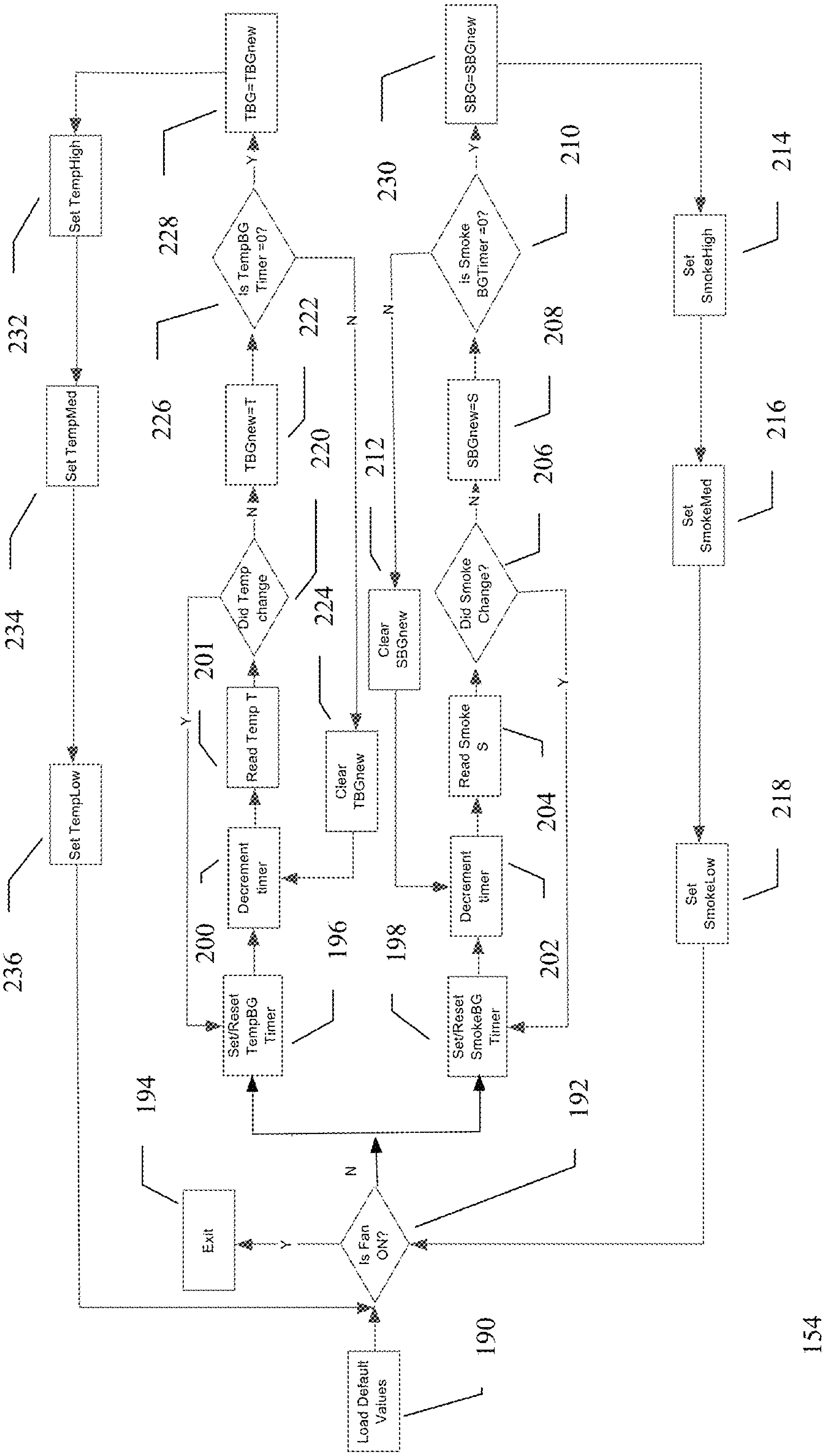

Load Default Values
190
Is Fan ON?
192
Y
Exit
194
N
Set/Reset TempBG Timer
196
Set/Reset SmokeBG Timer
198
Decrement timer
200
Read Temp T
201
Decrement timer
202
Read Smoke S
204
Did Smoke Change?
N
Y
SBGnew=S
206
Is Smoke BGTimer =0?
208
Y
N
SBG=SBGnew
210
Clear SBGnew
212
Set SmokeHigh
214
Set SmokeMed
216
Set SmokeLow
218
Did Temp change
N
Y
TBGnew=T
220
Is TempBG Timer =0?
222
Y
N
Clear TBGnew
224
226
TBG=TBGnew
228
230
Set TempHigh
232
Set TempMed
234
Set TempLow
236
154

Figure 9

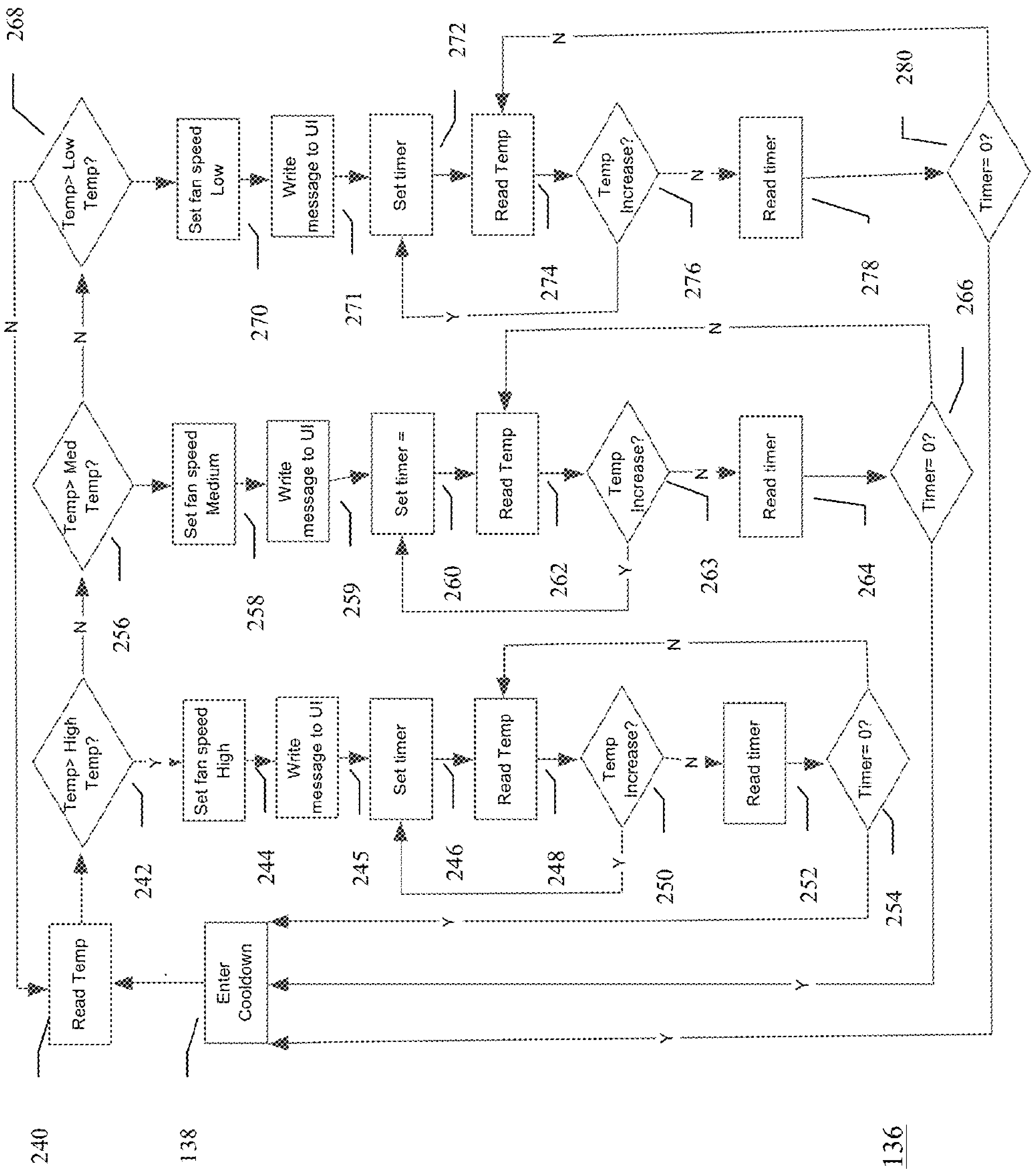

240
Read Temp
138
Enter Cooldown
136
242
Temp> High Temp?
Y
N
244
Set fan speed High
245
Write message to UI
246
Set timer
248
Read Temp
250
Temp Increase?
Y
N
252
Read timer
254
Timer= 0?
Y
N
256
Temp> Med Temp?
Y
N
258
Set fan speed Medium
259
Write message to UI
260
Set timer =
262
Read Temp
263
Temp Increase?
Y
N
264
Read timer
266
Timer= 0?
Y
N
268
Temp> Low Temp?
N
270
Set fan speed Low
271
Write message to UI
272
Set timer
274
Read Temp
276
Temp Increase?
Y
N
278
Read timer
280
Timer= 0?
Y
N

Figure 10

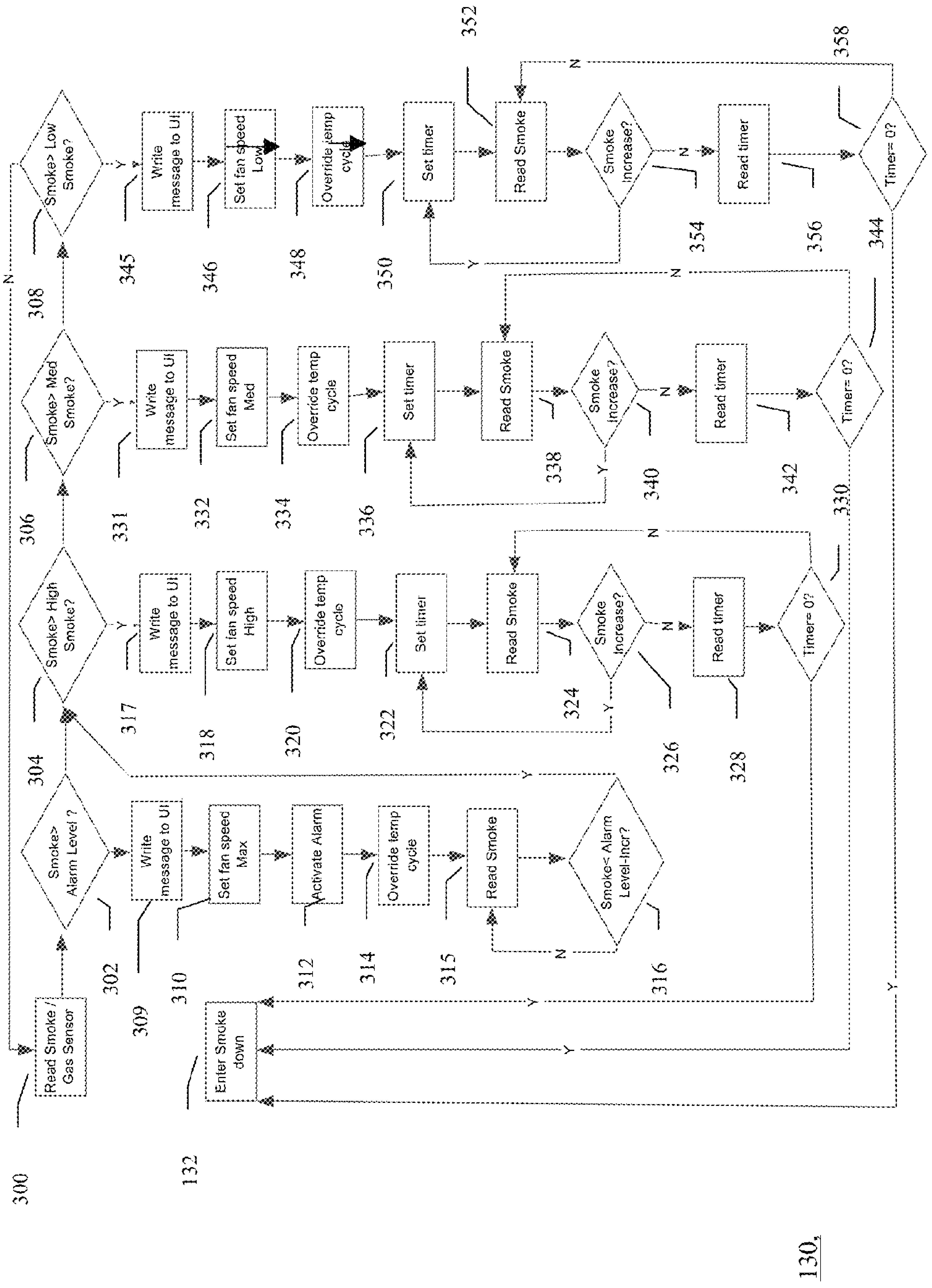

300
Read Smoke / Gas Sensor
302
Smoke> Alarm Level ?
Y
N
304
Smoke> High Smoke?
306
Smoke> Med Smoke?
308
Smoke> Low Smoke?
309
Write message to UI
310
Set fan speed Max
312
Activate Alarm
314
Override temp cycle
315
Read Smoke
316
Smoke< Alarm Level-Incr?
317
Write message to UI
318
Set fan speed High
320
Override temp cycle
322
Set timer
324
Read Smoke
Smoke Increase?
326
Read timer
328
Timer= 0?
331
Write message to UI
332
Set fan speed Med
334
Override temp cycle
336
Set timer
Read Smoke
338
Smoke Increase?
340
Read timer
342
Timer= 0?
330
345
Write message to UI
346
Set fan speed Low
348
Override temp cycle
350
Set timer
352
Read Smoke
Smoke Increase?
354
Read timer
356
Timer= 0?
344
358
132
Enter Smoke down
130

Figure 11

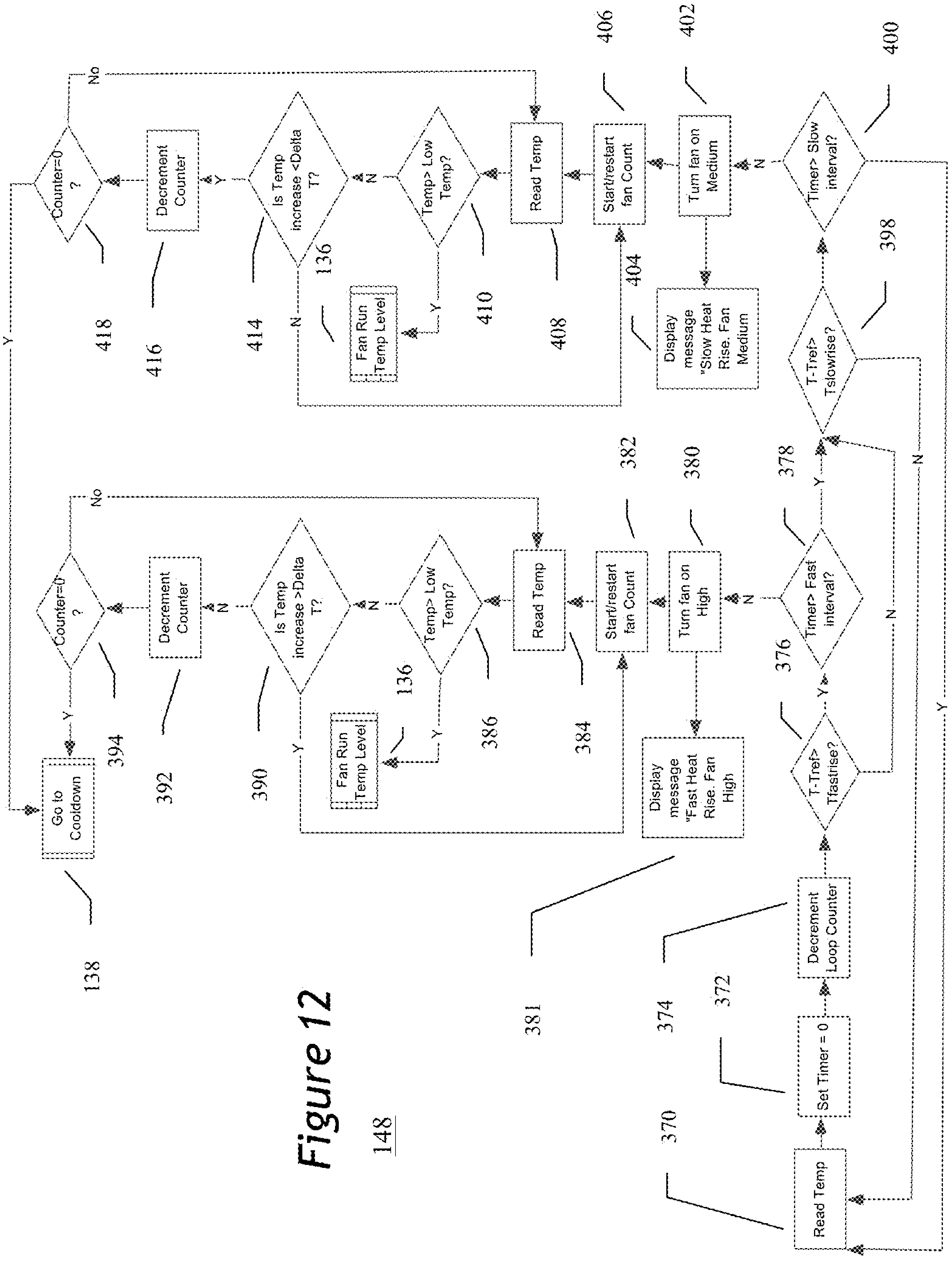

Read Temp
370
Set Timer = 0
372
Decrement Loop Counter
374
T-Tref> Tfastrise?
Y
N
Timer> Fast interval?
376
Y
N
Turn fan on High
380
Display message "Fast Heat Rise. Fan High
381
Start/restart fan Count
382
Read Temp
384
Temp> Low Temp?
386
Y
Fan Run Temp Level
136
N
Is Temp increase >Delta T?
390
Y
N
Decrement Counter
392
Counter=0 ?
394
Y
No
Go to Cooldown
138
378
T-Tref> Tslowrise?
398
Y
N
Timer> Slow interval?
400
Y
N
Turn fan on Medium
402
Display message "Slow Heat Rise. Fan Medium
Start/restart fan Count
404
406
Read Temp
408
Temp> Low Temp?
410
Y
Fan Run Temp Level
136
N
Is Temp increase <Delta T?
414
N
Y
Decrement Counter
416
Counter=0 ?
418
Y
No
148

Figure 12

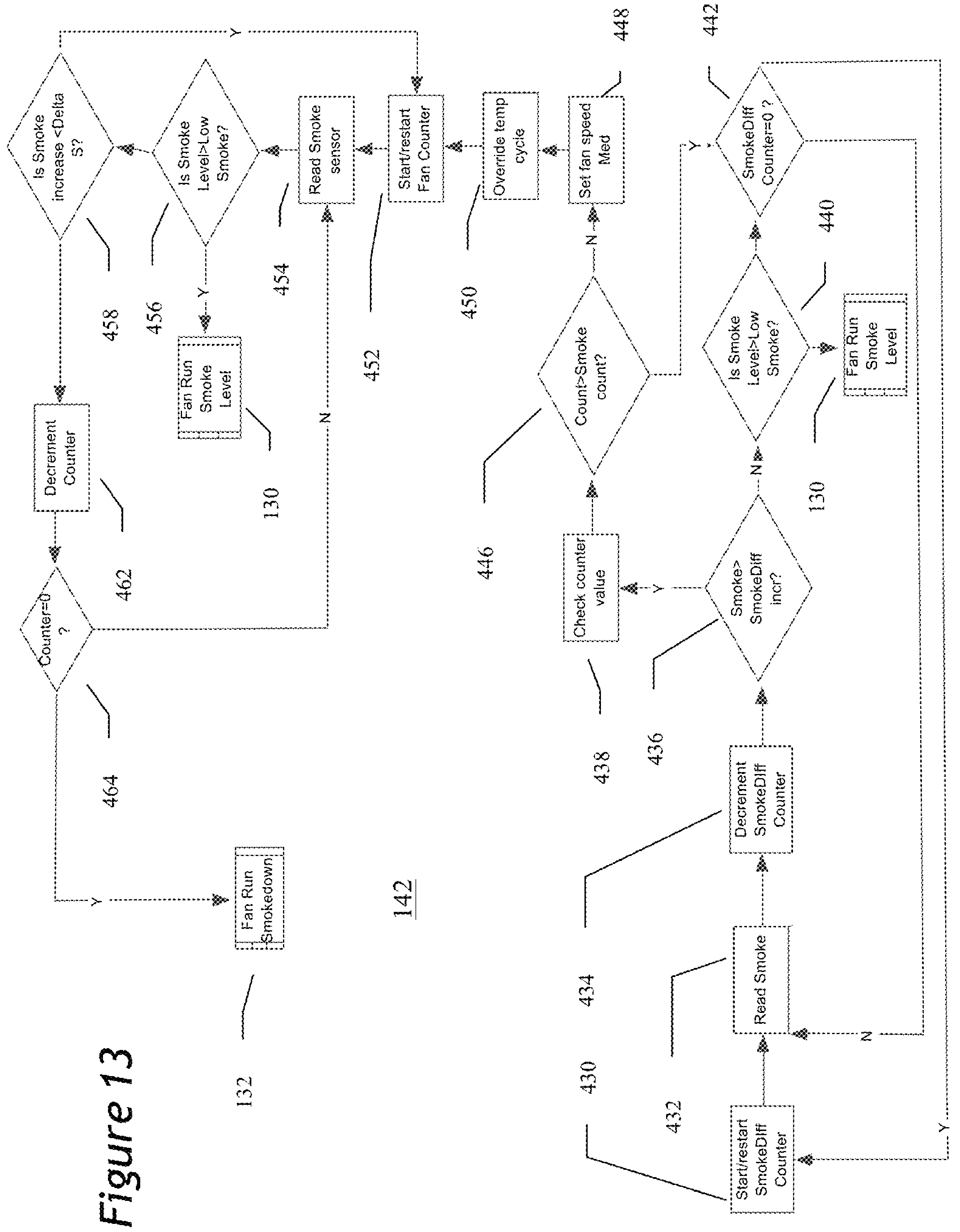

Is Smoke increase <Delta S?
Is Smoke Level>Low Smoke?
Read Smoke sensor
Start/restart Fan Counter
Override temp cycle
Set fan speed Med
Y
Y
N
N
Fan Run Smoke Level
Decrement Counter
Counter=0 ?
Fan Run Smokedown
Count>Smoke count?
Check counter value
Smoke> SmokeDiff incr?
Is Smoke Level>Low Smoke?
Fan Run Smoke Level
SmokeDiff Counter=0 ?
Decrement SmokeDiff Counter
Read Smoke
Start/restart SmokeDiff Counter
448
442
458
456
454
452
450
440
130
446
462
130
464
438
436
142
434
430
432
132

Figure 13

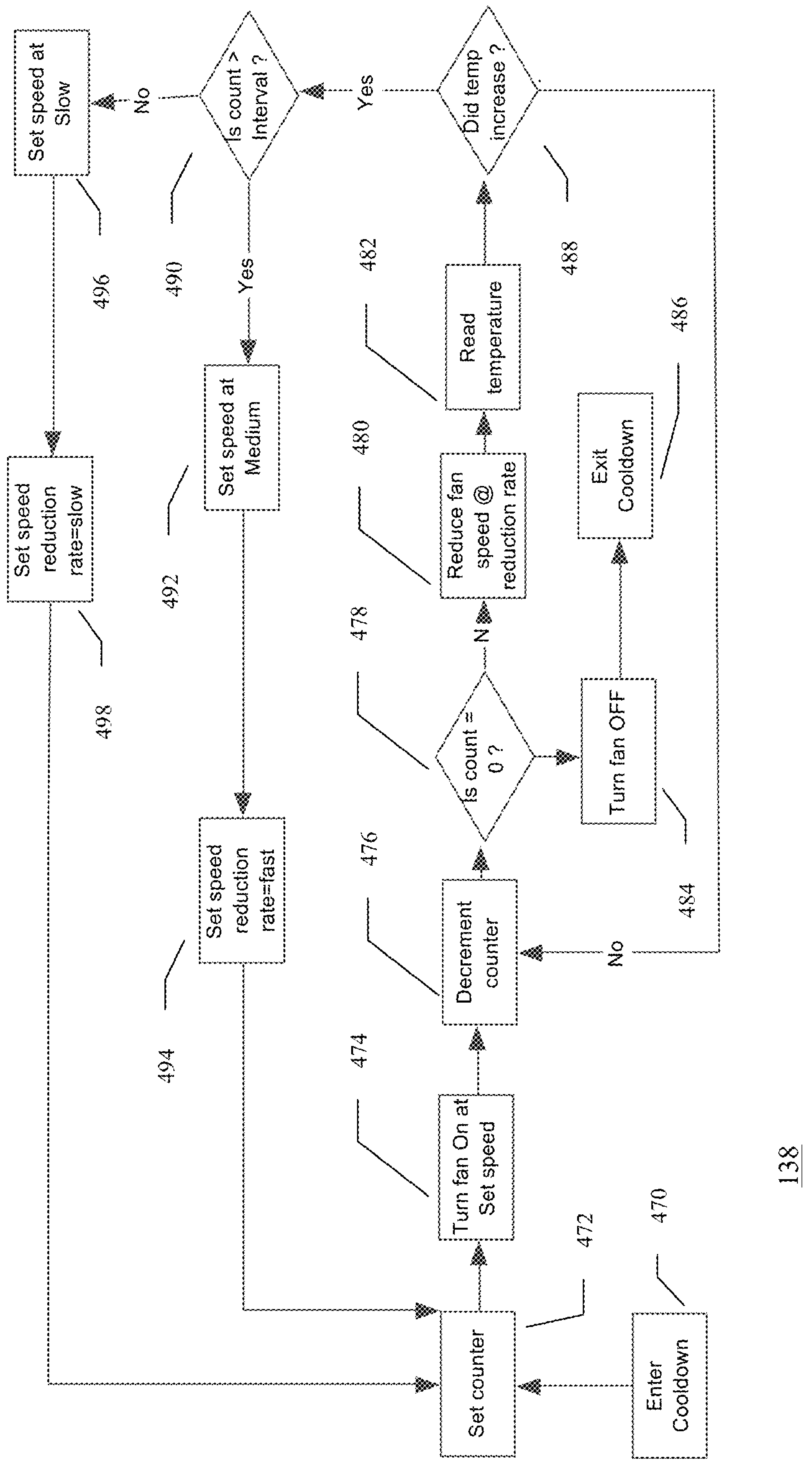

Enter Cooldown
470
Set counter
472
Turn fan On at Set speed
474
Decrement counter
476
Is count = 0 ?
478
N
Reduce fan speed @ reduction rate
480
Read temperature
482
Did temp increase ?
488
Yes
No
Is count > Interval ?
490
Yes
No
Set speed at Medium
492
Set speed reduction rate=fast
494
Set speed at Slow
496
Set speed reduction rate=slow
498
Turn fan OFF
484
Exit Cooldown
486
138

Figure 14

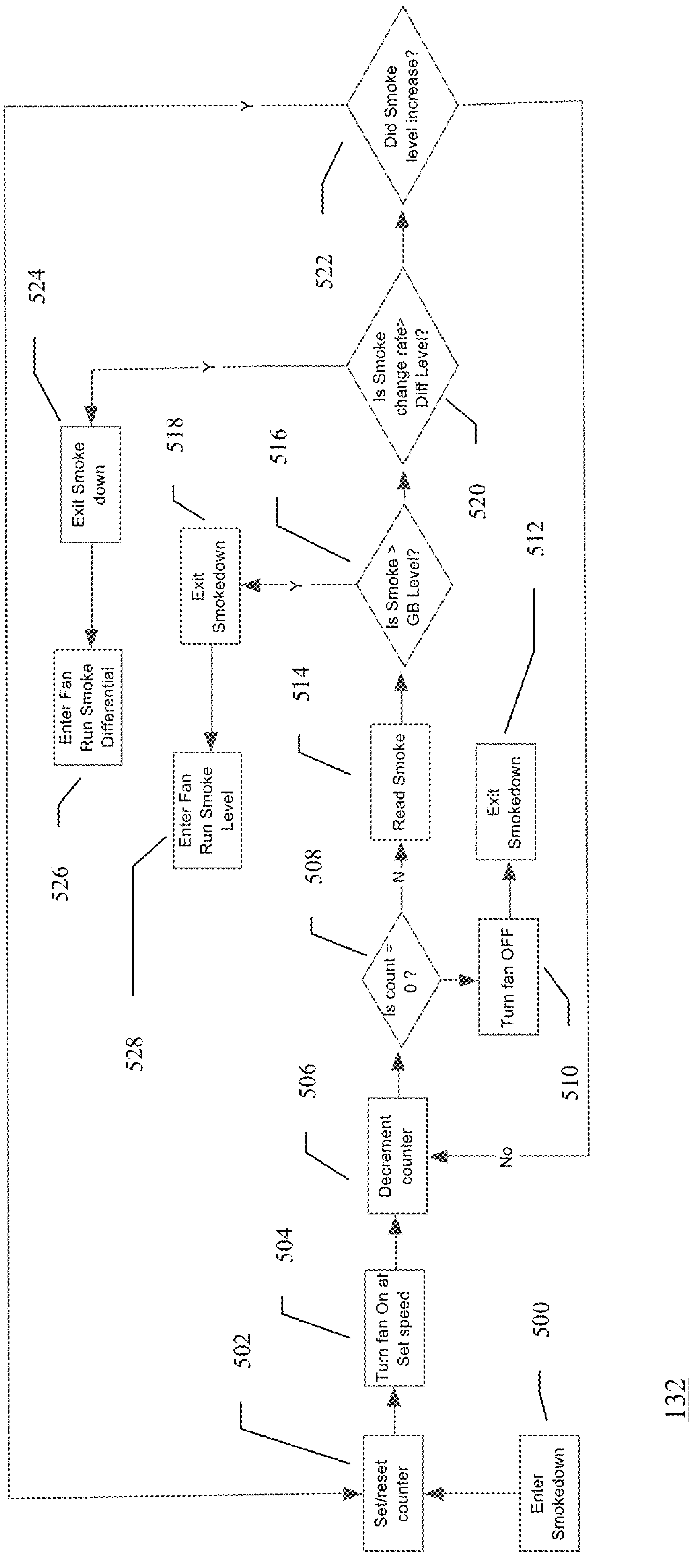

Enter Smokedown
500
Set/reset counter
502
Turn fan On at Set speed
504
Decrement counter
506
Is count = 0 ?
508
N
Turn fan OFF
510
Exit Smokedown
512
Read Smoke
514
Is Smoke > GB Level?
516
Y
Exit Smokedown
518
Enter Fan Run Smoke Level
528
Is Smoke change rate> Diff Level?
520
Y
Exit Smoke down
524
Enter Fan Run Smoke Differential
526
Did Smoke level increase?
522
Y
No
132

Figure 15

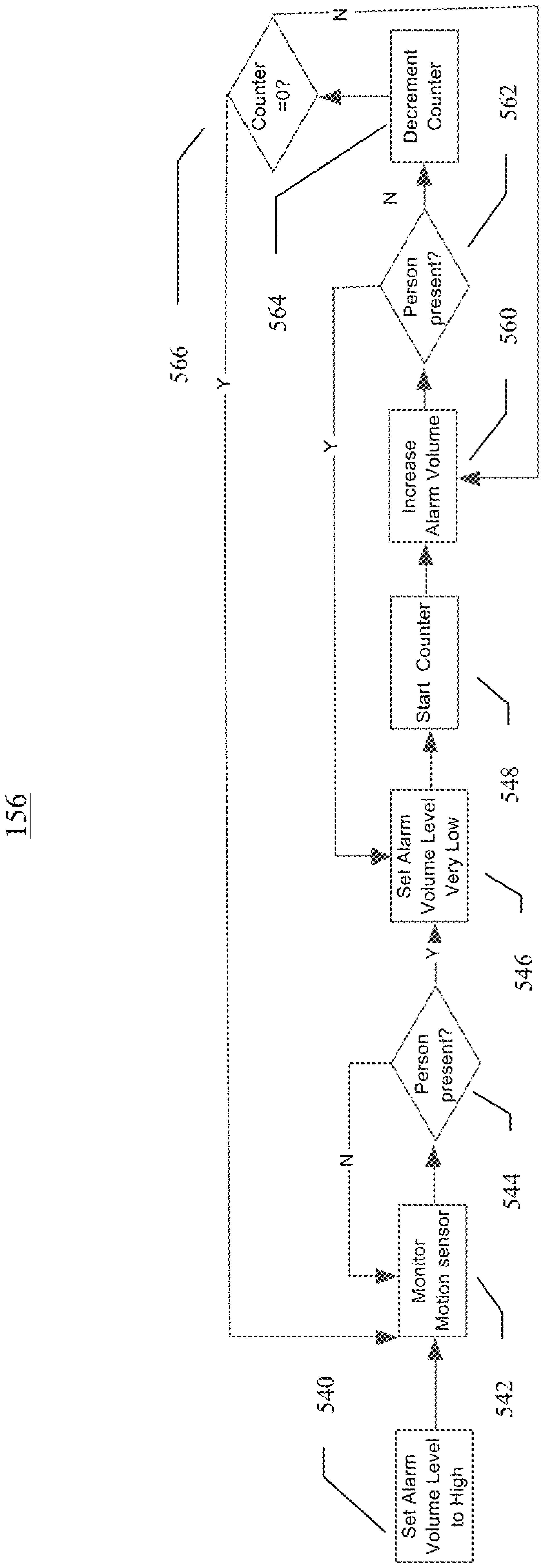

156
Set Alarm Volume Level to High
540
542
Monitor Motion sensor
544
Person present?
N
Y
546
Set Alarm Volume Level Very Low
548
Start Counter
Increase Alarm Volume
560
Person present?
Y
N
564
Decrement Counter
562
Counter =0?
N
Y
566

Figure 16

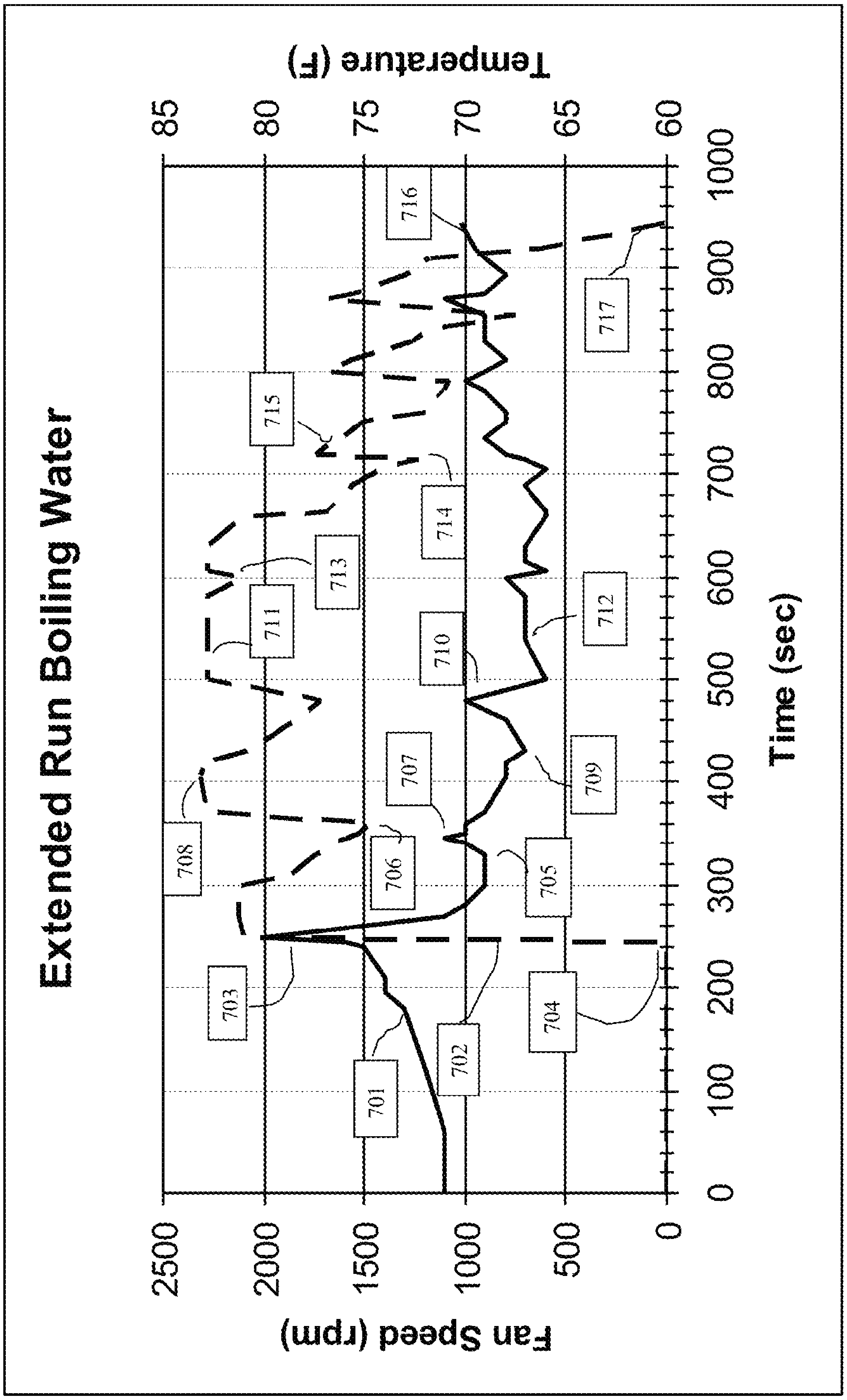

Extended Run Boiling Water
Fan Speed (rpm)
2500
2000
1500
1000
500
0
Temperature (F)
85
80
75
70
65
60
Time (sec)
0
100
200
300
400
500
600
700
800
900
1000
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717

Figure 17

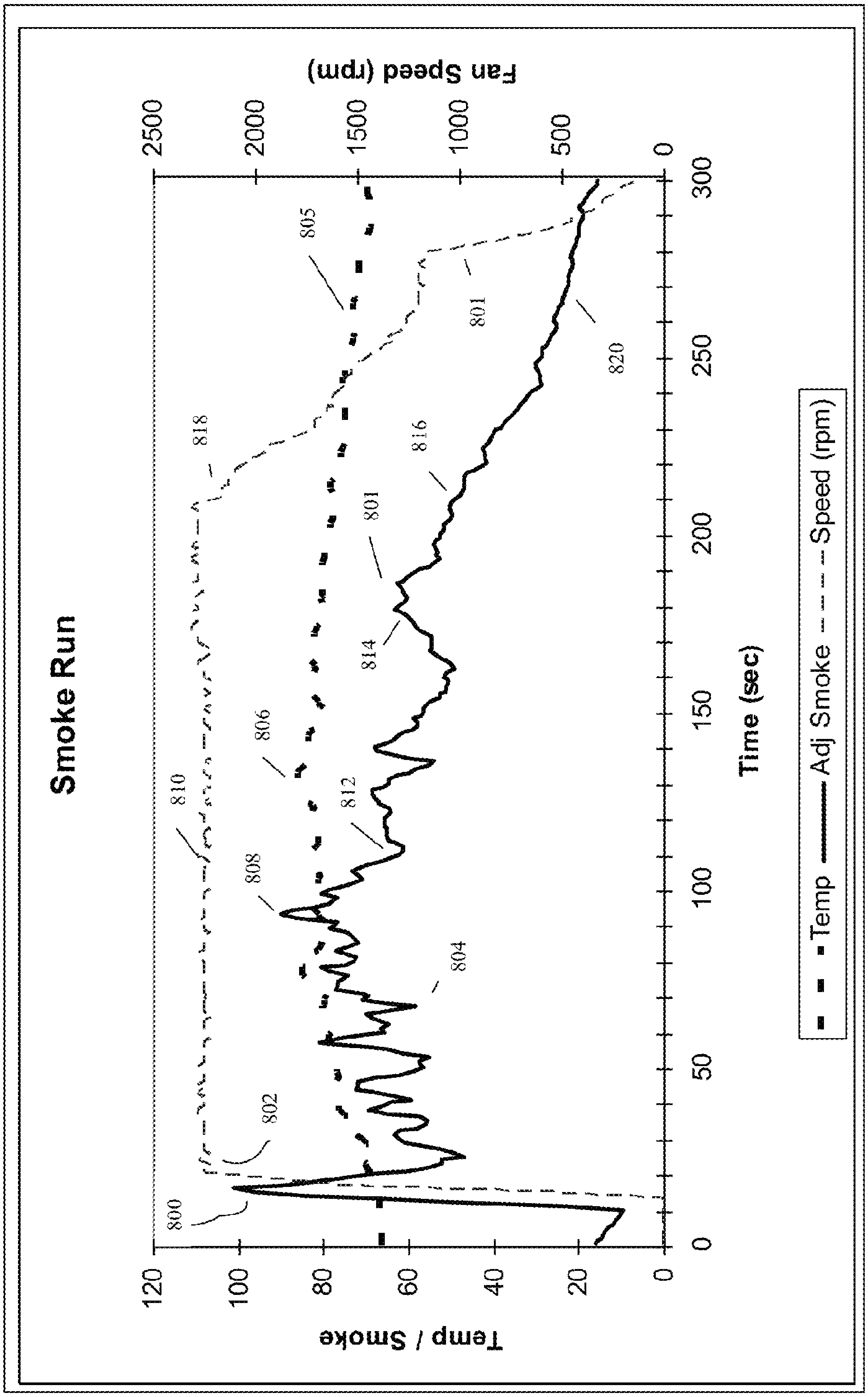

Smoke Run
Temp / Smoke
120
100
80
60
40
20
0
Fan Speed (rpm)
2500
2000
1500
1000
500
0
Time (sec)
0
50
100
150
200
250
300
Temp
Adj Smoke
Speed (rpm)
800
802
804
808
810
806
812
814
801
816
818
805
801
820

Figure 18

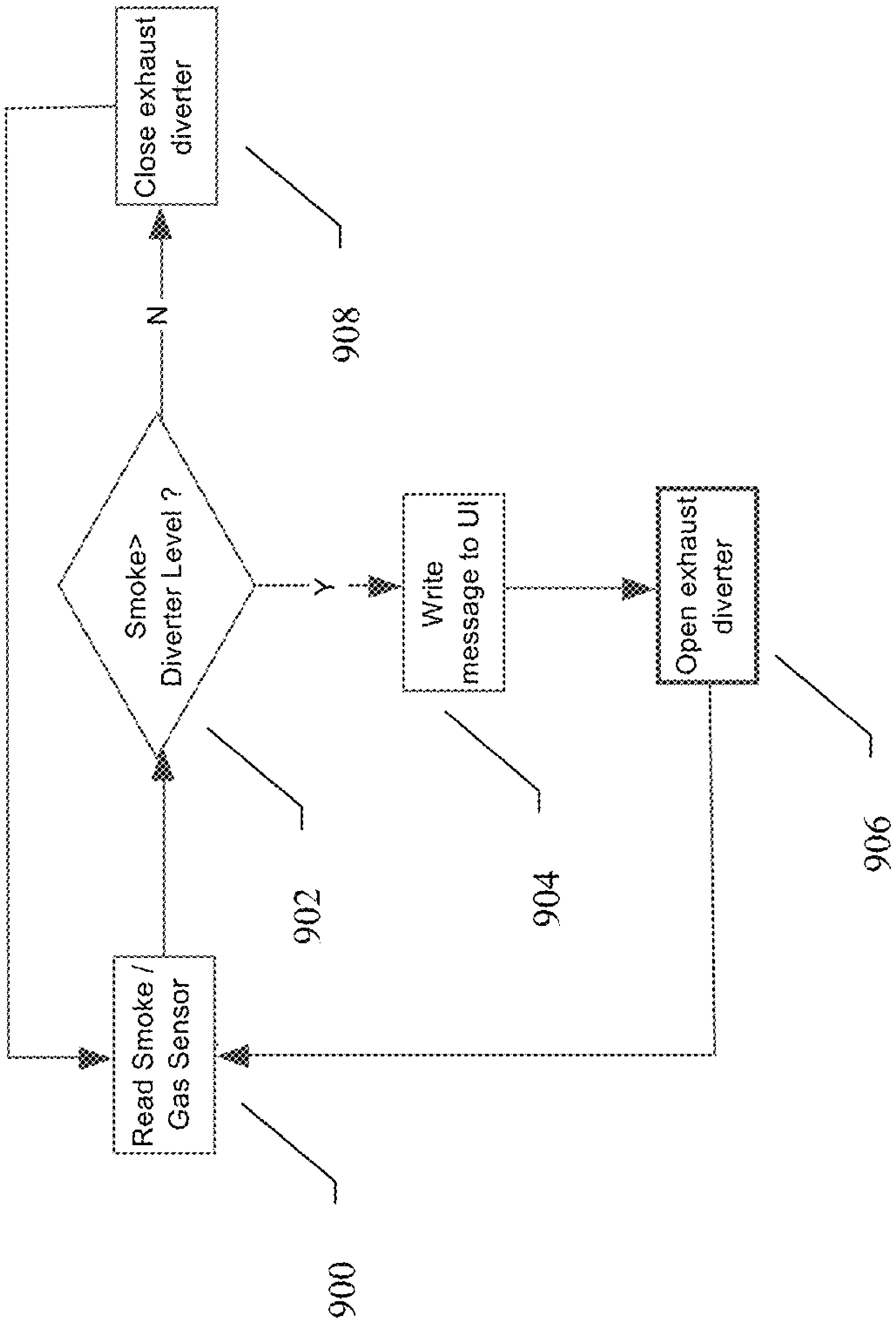

Read Smoke / Gas Sensor
Smoke> Diverter Level ?
Y
Write message to UI
Open exhaust diverter
N
Close exhaust diverter
900
902
904
906
908

Figure 19

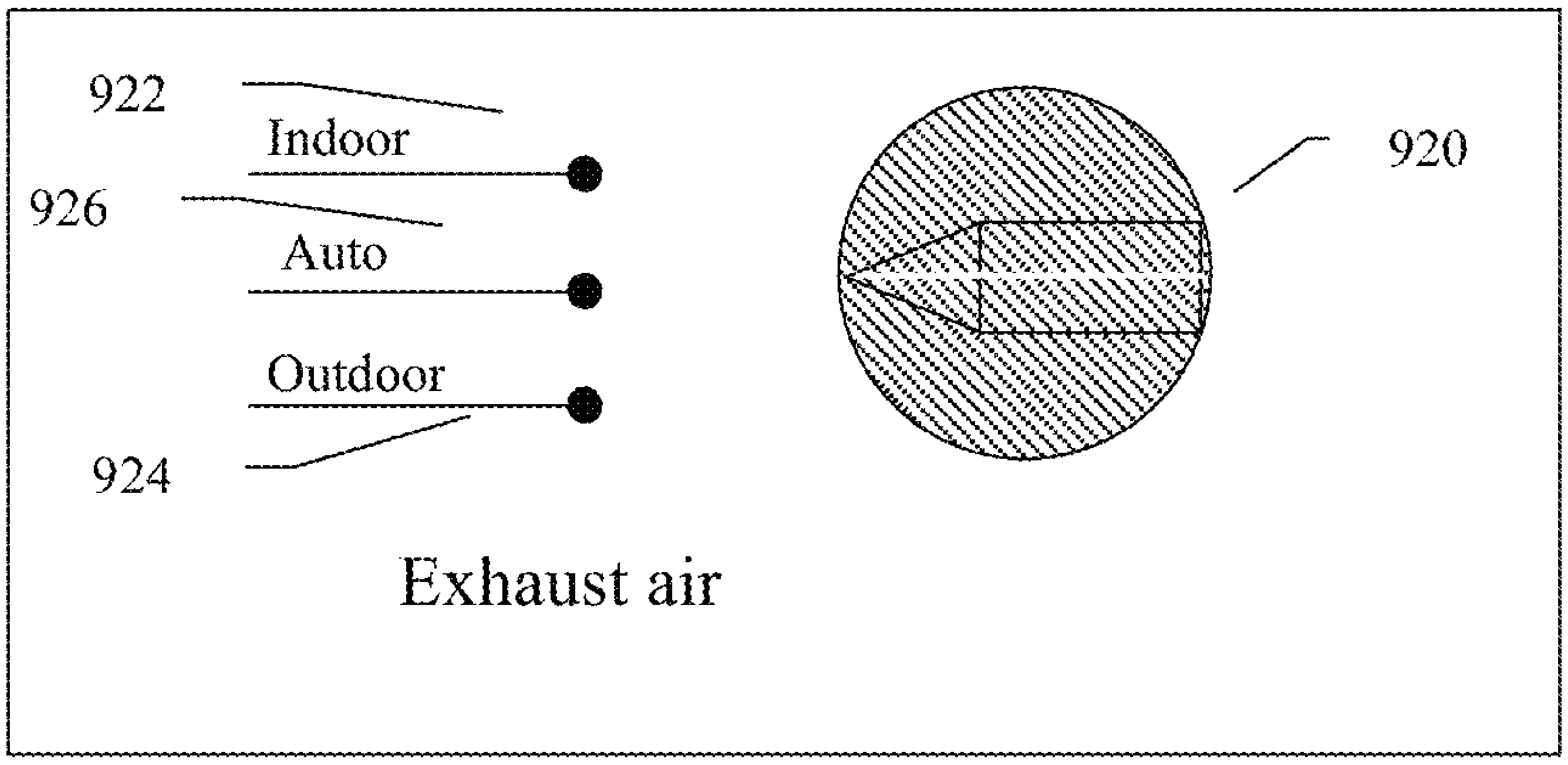


Figure 20

INTELLIGENT VENTILATING SAFETY RANGE HOOD CONTROL SYSTEM

FIELD OF THE INVENTION

This disclosure relates to the field of mechanical ventilation of enclosed, inhabited spaces and in particular, the ventilation of a kitchen where food is being cooked on a stove creating undesirable heat, moisture and airborne contaminants.

U.S. Pat. No. 6,920,874 by the same inventor describes an enhanced range hood with a control system that effectively modulates the speed of the exhaust fan in response to multiple air quality parameters. This disclosure extends the functionality of that disclosure incorporating a number of details that lead to improvements in the overall performance of the system. U.S. Pat. No. 6,920,874 entitled INTELLIGENT VENTILATING SAFETY RANGE HOOD is hereby incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

Modern homes are being built with increasing emphasis on energy efficiency. This generally means more thermal insulation, more vapor barriers and better quality seals around windows and doors. This type of construction has given rise to the concern that ventilation may be inadequate, in light of the need for a continuous supply of fresh air and concerns about volatile byproducts of manufacturing of synthetic items. There is further concern in the many homes that use combustible fuels for heating and cooking or lighting. In addition to the psychometric comfort factors of heat and humidity and the essential need for oxygen, there are the serious health factors of carbon monoxide, smoke, and any other products of combustion deriving from these combustion process. Excess heat and humidity in an enclosed structure can also be quite destructive to the structure itself, leading to problems ranging from mildew, to insulation failure, to deterioration of the actual structure itself through attraction of insects and rot. In the case of electric stoves, there are also harmful effluents emitted as the results of the cooking process.

As of 2011, there were anywhere between 200 and 700 annual deaths attributed to residential, non-vehicle, carbon monoxide (CO) poisoning in the US. While equipment malfunctions, such as cracked heat exchangers played a role, a key factor in all of these injuries and deaths was inadequate ventilation. Roughly 10% of these casualties have been attributed to gas stoves and ovens. Low-level cases are more difficult to track, since the symptoms are similar to common cold or flu, but are likely to have a much higher occurrence. Thus, considering the impact of lost work days and reduced activity due to illness for low-level exposure, and the injury and death resulting from high level exposure, the cost to society of inadequate ventilation in conjunction with combustion appliances is substantial.

The ASME standards for gas stoves, which allow for trace amounts of CO, are based on the assumption that the stoves are vented. However, many are not and even those that are generally use a range hood with a fan that must be switched on manually. Many people do not turn these venting fans on unless there is detectable smoke or odor or if the kitchen becomes excessively hot. In other words, kitchens are often inadequately ventilated to a degree that may be a health and safety concern.

Carbon monoxide, being colorless and odorless is undetectable without some sort of sensing device. It is unlikely

that CO being emitted by a cooking appliance will be detected by plug-in detectors since the installation instructions for these devices recommend placing them a minimum distance away from such appliances so as to avoid setting off an alarm due to transient levels emitted from said cooking appliances. In any case, while the alarms are useful for notifying building occupants of the hazard, they do nothing beyond this to ameliorate the situation. The same is true for smoke detectors.

Experts say that American households in general and kitchens in particular are seriously under-ventilated. Many homes are constructed with hoods that do not vent outdoors, and many people do not use their hoods routinely when cooking. They don't like the noise, or the fact that the hoods use extra power and remove conditioned air from the house. When they do use them, they often leave the room and forget to turn them off, which can waste a good deal of additional energy both from the fan itself and the loss of heated or cooled air.

A variety of range hoods have been developed in an attempt to provide ventilation of cooking-related exhaust fumes and other volatile waste products. Different designs are utilized including hoods mounted under cabinets, island hoods and down-drafting hoods that pull fumes from below. The vast majority are manually controlled and will not activate unless the user takes action. A few have implemented fairly simplistic automatic controls such as a single point temperature switch that turns the fan on at maximum speed when excessive temperature, smoke or fumes are detected. Others designed to operate in a commercial environment, vary fan speed in response to effluent factors but cannot turn the fan off due to health code and other restrictions that are unique to a commercial cooking environment. Since, in the commercial environment, the fan is always running at some ventilation level, there is no need for detection of small quantities of hazardous chemicals like carbon monoxide. This means that they can function satisfactorily with a far more simplistic detection scheme than what is required in the residential environment. While these and other devices represent improvements in the art of ventilating heat and fumes generated by cooking, they either do not adequately address the health and safety concerns described above, or they lack the sophistication that will allow them to fit seamlessly into a modern household without being disruptive.

One reason that automatic range hood controls have not yet been popularized is because designing one that works effectively is difficult. Unlike a household furnace, whose thermostat can effectively control the temperature in the house since it controls the source of the heat, a range hood controller has no control over the source of the heat or the fumes or the steam. Therefore it must react without knowledge of what the stove is doing or whether the heat or smoke it just detected is increasing, decreasing or being produced at a steady rate. This is exacerbated by the fact that once the fan is running, it is difficult to tell what is happening below. This makes it particularly problematic to determine when it is time to turn the fan off. Conventional approaches might tend towards a timer-based approach (open loop), which essentially guesses how long the cooking episode will last, and thus runs the risk of either terminating ventilation prematurely, leading to the possibility of spillage of smoke or fumes, or running too long, on the other hand, thereby wasting energy.

Conversely, a closed-loop approach that relies solely on the sensors will likely need to turn the fan off in order to see if more smoke and heat are still coming up. This could lead to a lot of rapid up and down cycling of the fan during the cooking process that, since it is in the kitchen, a place where people often assemble, could be considered objectionable on account of the rapidly changing noise level.

Understanding this shows why a simple temperature set level control like the type used on a furnace, even with hysteresis built in will not be sufficient.

The problem of knowing when to automatically turn a ventilation hood on and off is sometimes addressed by means of a direct electrical connection between the stove and hood, or the use of some external device that could be attached to the stove to determine whether or not gas or electricity is flowing, or even an AC coupling scheme that transmits signals through household wiring. This however, has the drawback of added cost and complexity and the fact that most hoods and stoves are not designed to operate together. Furthermore, even if the amount of gas or electricity could be measured, that would still not directly correlate with the need for ventilation, to be able to distinguish, for example, between a pan full of food that is burning and giving off smoke, and a tea kettle that is simply heating up.

In order to provide optimal performance, it is ideally useful to know precisely, the amount of ventilation required, so as to avoid over-ventilation which can waste a good deal of energy.

For these reasons, plus, for simplicity of installation, a self-contained hood system with a controller that will be able to not only detect the need for ventilation but to determine the amount of ventilation required at any point before, during, or after the cooking process might be desirable.

Such a system would need to address several considerations. First, it would be likely to require some means to determine the dynamic ventilation requirement. This can be accomplished by means of air quality sensors that can assess not only the operating state of the stove, but also the amount of undesirable byproducts being produced. The placement of these sensors can be important in the operation of the hood. Placing them in direct communication with the ventilation air stream provides the most responsive performance, though care would need to be taken to dampen the effect of relatively abrupt changes in temperature or contaminant levels as the fan turns on which might otherwise lead to unstable performance. Response time is also quite important, so that the fan becomes activated before contaminants begin spilling out of the hood.

There is also the question of environmental variability. A robust automatic hood controller would need to function in a wide variety of geographies exhibiting a wide range of background temperature, humidity and contaminant levels. A controller that responds to a fixed preset temperature level or a fixed contaminant level, will perform differently in different environmental settings producing less than ideal results under non-standard conditions.

The above-mentioned considerations suggest the need for a device to address these concerns, that would provide an effective, self-contained, inexpensive, convenient, non-intrusive automated response to the presence of the air quality factors such as heat, humidity, CO and smoke and fumes or other similar hazards in a kitchen as the result of cooking or introduced by some other means, independent of background conditions.

Such a device might also include an alarm feature. There are, of course, various types of smoke and carbon monoxide detectors. These devices are sensitive to the presence of the hazards they are intended to detect and are designed to emit a loud audible alarm when a predetermined level of hazard has been detected. This is, of course, useful and has in many cases saved lives, but there are other cases where they have not been effective. Having the ability to take action beyond emitting an alarm, by, for example, providing ventilation could also prove useful.

In providing this capability in conjunction with a ventilation device that is located in very close proximity to where people are cooking, it might be helpful to be able to automatically adjust the volume level of the alarm so as not to be able to provide the necessary function without being overwhelming.

The approaches described in this section could be pursued, but are not necessarily approaches that have been previously conceived or pursued. Therefore, unless otherwise indicated herein, the approaches described in this section are not prior art to the claims in this application and are not admitted to be prior art by inclusion in this section.

BRIEF SUMMARY OF THE INVENTION

The disclosure describes a number of enhancements to a conventional stove hood, or range hood to increase its effectiveness, ensure its proper utilization and increase its energy efficiency by means of an automatic controller.

The automatic controller consists of some number of air quality sensors that might include temperature and smoke, at a minimum, as well as humidity, gas, and others for enhanced performance, and well as the electronic circuits capable of capturing and conditioning the signals from those sensors so as to provide input to a microcontroller, a set of software instructions for the microcontroller to interpret the signals and generate responses by controlling both the ON/OFF state of the fan as well as its speed, and the electric circuitry necessary to drive an electric (AC, DC or EC) fan.

The art described herein addresses solutions to certain key issues that arise in the implementation and development of a smart hood controller that fall variously under the heading of operability, environmental variability, sensor variability, minimization of undesirable effects such as noise and energy loss, and overall system performance.

The disclosure describes a way of managing the dynamic timing of the fan control, by means of software so as to provide smooth behavior that will not be considered "jerky" or intrusive to the user. In some cases, for example, fan operation is initiated when a guard band threshold level has been reached for any parameter. The software ensures that the fan will remain ON for a minimum length of time. This capability is enabled through a set of software routines for heat, smoke, etc., that control the fan in response to a fixed threshold level being reached. The software also continues to monitor the sensors throughout the run time so that if the fan speed needs to be increased, it will do so.

The disclosed controller addresses the question of sensitivity loss when the fan is running by gradually reducing the fan speed to the point where it can effectively resample the air quality coming into the hood. This scheme, which combines elements of both open-loop and closed-loop control, provides a smoother and more efficient operation, since the fan remains ON at low speed, while the controller continues to sample and respond to changes in the air quality until it has determined that cooking has concluded. This capability is contained in a set of software routines for heat, smoke, etc., specific to the task of ramping down the hood operation where it appears that cooking has been completed. By reducing fan speed and turning the fan OFF in a timely manner, energy savings are achieved.

As to the question of environmental variability, the present disclosure describes a control system that replaces the fixed levels for each air quality threshold, with a "learning" scheme that adjusts itself to its surroundings in two ways.

First, by sampling the background level during idle periods, it establishes reference levels for each parameter, relative to which guard band levels are computed. This is accomplished by means of a series of software routines for heat, smoke, etc., that run during idle periods and are assigned to the task of establishing the ambient conditions so that threshold trigger levels can be set relative to those.

Secondly and independently, the system responds to rates of change in each parameters rather than only absolute fixed values. So, a rate of change condition will also trigger a fan response, regardless of whether a guard band level has been reached. This rate-detection approach is used to effectively respond to differential rates of air contamination rather than fixed levels. In this case the response is proportional to the rate of change. This capability is provided by means of a set of software routines for heat, smoke, etc., that control the fan in response to a detected rate of change.

The controller also contains an optional audible alarm feature. This can be helpful under a high smoke condition, though it can also be annoying, If the customer is cooking some smoky food, he or she would not want a loud alarm going off in his or her face. Therefore a motion detector is employed to determine whether or not a person is standing in front of the stove and adjust the alarm volume and behavior accordingly. This feature is accomplished by means of a software routine that adjusts the volume of the audible alarm in response to the presence of a person in proximity to the stove as determined by a motion detector or other means of determining whether the space around the stove is occupied.

These and other aspects of the disclosed subject matter, as well as additional novel features, will be apparent from the description provided herein. The intent of this summary is not to be a comprehensive description of the subject matter, but rather to provide a short overview of some of the subject matter's functionality. Other systems, methods, features and advantages here provided will become apparent to one with skill in the art upon examination of the following FIGURES and detailed description. It is intended that all such additional systems, methods, features and advantages that are included within this description, be within the scope of any claims filed later.

BRIEF DESCRIPTIONS OF THE DRAWINGS

The novel features believed characteristic of the disclosed subject matter will be set forth in any claims that are filed later. The disclosed subject matter itself, however, as well as a preferred mode of use, further objectives, and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

FIG. **1** is an elevation view of a typical overall smart hood embodiment.

FIG. **2** is a plan view looking up from underneath the hood so that the fan can be seen.

FIG. **3** is an alternative configuration showing an external control module that can be added to an existing hood installation.

FIG. **4** is a functional block diagram of one embodiment of the hood control system.

FIG. **5** is a schematic drawing of an example circuit.

FIG. **6** is a schematic of the printed wiring board assembly that contains the microprocessor as well as the input-output portion of the controller.

FIG. **7** is a flow chart of the main program which gives an overview of the software, including various subprograms.

FIG. **8** is a flow chart of the Air quality monitoring subprogram, which describes the "ready" mode.

FIG. **9** is a flow chart of the Set Guard Band Level subprogram which determines the trigger levels for each of the air quality sensors based on the background conditions.

FIG. **10** is a flow chart of the Temperature Run Level subprogram which controls fan operation when the temperature reaches one of the guard band levels.

FIG. **11** is a flow chart of the Smoke Run Level subprogram which controls fan operation when the smoke level reaches one of the guard band levels.

FIG. **12** is a flow chart of the Temp Differential subprogram which controls fan operation when the temperature rise rate reaches one of the preset thresholds.

FIG. **13** is a flow chart of the Smoke Differential subprogram which controls fan operation when the smoke rise rate reaches one of the preset thresholds.

FIG. **14** is a flow chart of the Cooldown subprogram which controls the fan ramp down procedure as the heat in the system begins to decrease.

FIG. **15** is a flow chart of the Smokedown subprogram which controls the fan ramp down procedure fan as the smoke level in the system begins to decrease.

FIG. **16** is a flow chart of the Alarm Behavior subprogram that controls the interaction of the motion sensor and the audible smoke alarm feature included in some embodiments.

FIG. **17** is a time history chart showing one embodiment of the control system's response to a boiling water operation.

FIG. **18** is a time history chart showing one embodiment of the control system's response to the introduction of smoke into the hood.

FIG. **19** is a flow chart of the operation of the Diverter Check subprogram.

FIG. **20** shows one embodiment of a control panel switch that could be used with an automatic indoor/outdoor control option in conjunction with the Diverter Check subprogram.

In the FIGURES, like elements should be understood to represent like elements, even though reference labels are omitted on some instances of a repeated element, for simplicity.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Reference now should be made to the drawings, in which the same reference numbers are used throughout the different figures to designate the same components.

For the reasons described above, plus, for simplicity of installation, a self-contained hood system with a controller that will be able to not only detect the need for ventilation but to determine the amount of ventilation required at any point before, during, or after the cooking process might be desirable.

Such a system would need to address several considerations. First, it would be likely to require some means to determine the dynamic ventilation requirement. This can be accomplished by means of air quality sensors that can assess not only the operating state of the stove, but also the amount of undesirable byproducts being produced. The placement of these sensors can be important in the operation of the hood. Placing them in direct communication with the ventilation air stream provides the most responsive performance, though care would need to be taken to dampen the effect of relatively abrupt changes in temperature or contaminant levels as the fan turns on which might otherwise lead to unstable performance. Response time is also quite important; the fan needs to become activated before contaminants begin spilling out of the hood.

There is also the question of environmental variability. A robust automatic hood controller would need to function in a wide variety of geographies exhibiting a wide range background temperatures, humidity and contaminant levels. A controller that responds to a fixed preset temperature level or a fixed contaminant level, will perform differently in different environmental settings producing less than ideal results under non-standard conditions.

Another consideration would be sensor drift over time, either through deterioration or wear of the sensing elements or in an operating environment such as this, by contamination by such factors as grease, dirt, etc, that can accumulate on the sensor surfaces, resulting in changes to their response characteristics. A controller with the capability of auto-calibration can continuously adjust for these changes, and compensate for them to ensure consistent performance over long periods of time.

A robust hood control system would also be expected to function equivalently in conjunction with a variety of different stove types, such as gas, electric, convection, etc., with different heat output and fume generation rates, requiring a wide range of performance characteristics in order to meet the intended design objectives.

The above-mentioned considerations suggest the need for a device to address these concerns, that would provide an effective, self-contained, inexpensive, convenient, self-adjusting, non-intrusive automated response to the presence of the air quality factors such as heat, humidity, Carbon monoxide, smoke and fumes or other similar hazards in a kitchen as the result of cooking or introduced by some other means, independent of background conditions.

Such a device might also include an alarm feature. In providing this capability in conjunction with a ventilation device that is located in very close proximity to where people are cooking, it might be helpful to be able to automatically adjust the volume level of the alarm so as to be able to provide the necessary function without being overwhelming. Otherwise there might be a tendency on the part of the customer to disable the alarm.

In FIG. **1** we see one embodiment of the controller embedded in a range hood assembly **10**, in which the hood enclosure **16**, is vented outdoors through the vent outlet **12**. Other embodiments could include any of several hood configurations, such as a freestanding hood, downdraft hood, etc. The fan can operate in the automatic or manual mode as determined by the position of the Auto/Manual switch **17**. In the Manual mode, the speed is controlled by the speed control knob **18**. In some embodiments, the functions of the control knob **18** and the Auto/Manual switch **17** may be replaced by digital controls. In some embodiments, sensitivity controls for Temperature **13**, Smoke **15**, or other air quality parameters could be added to allow the customers to individually adjust the responsiveness of the automatic control system for each parameter. Alternatively, a single sensitivity control could be used to adjust the overall sensitivity. In some embodiments, the unit may also be equipped with an audible alarm **14** to notify users if there is a hazardous condition and a motion detector **19** to determine if anyone is standing in front of the stove. This information may be used to adjust the behavior of the alarm or to provide other features. An LCD display panel **21** provides textual information to notify the user of the operational state of the hood, and what hazards it is responding to. While an LCD display panel **21** is used in this embodiment, other embodiments may use other display panels, for example, one or more LEDs, an analog display panel, etc. Further, the location, placement and orientation of the features shown in FIG. **1** may differ in other embodiments.

FIG. **2** shows one embodiment of the underside of the hood assembly **16**. The fan **20** is driven by the fan control module **24**, which contains a temperature sensor **22** and an air quality sensor **26** in Auto mode. Other embodiments could include multiple fans. The air quality sensor **26** is capable of detecting the presence of smoke, carbon monoxide and other organic compounds and it provides an output signal that is proportional to the amount of smoke and/or pollution in the air. While this embodiment shows the sensors contained within the module, they could also be located remotely and connected to the module through wires or wirelessly. The location of the sensors is important as it can affect the response time, the operational dynamics and the overall sensitivity of the system. In this embodiment, the sensors are placed directly in contact with the air flow.

FIG. **3** shows an embodiment where the controller is connected to an existing hood as an add-on accessory. The figure shows the hood enclosure **16**, vent outlet **12**, Auto/Manual switch **17** and manual speed control **18**. Mounted below this hood and electrically connected in a manner which intercepts the circuit between the speed control and the fan is the accessory controller **36**, including temperature sensor **38** (for example, thermistor, thermocouple, etc) and air quality sensor **42** (for example, smoke sensor, CO sensor, optical sensor, electro-chemical sensor, etc.), humidity sensor **32** (for example, capacitive, resistive, thermal conductive, etc.), and motion detector **34** (for example, IR, ultrasonic, etc.). Some type of user interface, such as LED indicators **30**, shown here, can be provided. Other embodiments might include, incandescent lights, an alphanumeric, or graphical, or video display. This embodiment also includes an audible alarm **40** which could be a beeper, a buzzer, a siren, etc.

FIG. **4** shows a functional block diagram of one embodiment of the hood control system. It depicts a variety of air quality sensors, such as temperature **50**, smoke **52**, carbon monoxide **54** and humidity **56**. These provide input signals to the micro-controller logic IC **62**, along with the control panel inputs **58**, by way of the signal conditioning circuitry **60** which provides power to the sensor as well as any filtering that would be applied as standard practice in any signal input application. Power for the electronics is provided by a power supply **66** at the voltages appropriate for the devices being used. The power supply **66** of the current embodiment is generally DC, but other embodiments may use AC, battery supply, a combination of power supplies, etc. The micro-controller then acquires these input voltages, digitizes them, and using the embedded algorithms, generates outputs in the form of messages to be displayed on some form of user interface such as an LCD panel **64**, as well as drive signals to be sent to a motor drive circuit **67** which provides the appropriate level and type of electrical power to the fan **68**, such as, for example, pulse-width modulated (PWM) energy, be it AC or DC, sufficient to drive the fan **68** in a variable speed manner. Straight DC power can also be used, or AC power, speed controlled by a TRIAC or similar type of circuit.

FIG. **5** is a schematic of one embodiment of the AC circuit that provides the power for the smart range hood controller and the fan in the case where an AC fan is used. As the AC power enters the circuit at **72** it is routed to the lamp **74** through the lamp switch **88**, and to the Auto/manual switch **76**. In the manual mode, power flows through the manual speed control potentiometer **78** to the motor driver **80** and then to the fan **84** via the TRIAC elements **86** and the RFI filter network **82**. In the Auto mode, it energizes the DC power supply **70**, bypassing the manual speed control potentiometer **78**. Instead of the potentiometer, a series of pulses or other control signals or voltages generated by the microprocessor will be fed to the motor driver, which will convert them and amplify them as needed, to a type and level that can be used to drive the fan. The rest of the circuit to the fan **84** is the same as in manual mode.

Referring to FIG. **6**, we see a more detailed schematic of one embodiment of a printed wiring board assembly (PWBA). The figure is divided by a dashed line. Above the line is the low-voltage DC portion of the circuit that handles the inputs, the data processing, and the user interface. Below the line is the AC line-voltage portion which handles the output to the fan. In this embodiment, the DC portion, a voltage control circuit **90** reduces the power supply voltage to the circuit operating voltage. A smoke/gas sensor **92**, which could have an embedded heater **94**, and temperature sensor **96** are connected to microprocessor **102** as analog inputs through pull-up resistors **100**. An additional sensor (e.g. humidity) can be added on spare input line **98**. The microprocessor **102** executes software code that responds to these inputs as directed by the setting of the DIP switch **104** which provides configuration option settings (e.g. gas or electric stove, sensitivity adjustment range, seasonal adjustment). Motor speed control signals are sent to the AC portion of the circuit through a diode **108** and an optical isolator **114**. The current state of the system is communicated to the customer by means of signals directed through a driver resistor network **106** to a user interface **110** which could be a LCD or other visual display or audio device. A reset button **95** can be used to restart the software program in the event of a malfunction or if the customer wants to shut the fan off without waiting for the cycle to complete. In the AC portion of the circuit, in Auto mode, AC line voltage comes in at AC input **111** where it is modulated by control signals as it passes through a TRIAC device **112** to drive the AC output **113**, which drives the fan subject to filter circuit **118**. In manual mode the TRIAC **112** is controlled by a panel mounted potentiometer **116**.

The software used to provide the intelligence to the hood operation can be represented as a main program and a series of subroutines, though it need not be structured that way in practice as long as the necessary functions are provided. The software combines aspects of both open-loop and closed-loop control, with timers making sure that once activated, the fan runs for at least a minimum amount of time, and sensors constantly monitoring the air quality to allow the system to respond to changes by moving into other operating modes as required.

The diagrams in this embodiment depict a smoke sensor, which in other embodiments could also be a gas sensor, capable of responding to various organic compounds including carbon monoxide, or a combination smoke/gas sensor. In all cases the software will respond in a similar manner. For simplicity's sake, there is no humidity sensor shown in this embodiment, but for embodiments that include a humidity sensor, the software may handle it in the same manner as the temperature sensor shown here.

The software essentially monitors the air quality sensors and controls the fan in response to them. In some embodiments, there are two different response modes, a level response, where the fan comes on in response to a level, which could be considered a guard band, being reached, and a differential response, where the fan is activated in response to a detected rate of increase in a parameter such as temperature or effluent. In both cases the fan is activated at a speed that is appropriate to the detected requirement. The levels are initialized at factory preset levels, though the system also has a learning capability where it self-adjusts guard band levels based on background conditions.

FIG. **7** is a flow chart giving a functional overview of one embodiment of the software. The program begins at **120** at power up or after a reset when the microprocessor is initialized. A countdown timer **122** is set which establishes an execution loop. This is followed by the initiation of the "Air Quality Monitoring" routine **126**. The routine proceeds through the loop, checking the sensors, and decrementing the counter at **124**. If, at **128** the Smoke Level is measured to be above a preset trigger level, the Fan Run Smoke Level routine **130** will run, followed by the Diverter check **131** which can set the position of an exhaust damper for indoor or outdoor exhaust depending on the level of smoke contained in the exhaust stream. This is followed by Fan Run Smokedown routine **132**, which contains the logic necessary to terminate fan operation. This routine, upon completion, brings the system back to the beginning where the countdown timer is reset **122** and where monitoring **126** can resume. Likewise, if the measured temperature exceeds one of the preset, or self-adjusted, temperature thresholds **134**, the routine will branch to the Fan Run Temp Level **136** followed by the Fan Run Cooldown **138**. Each of these routines is described in a separate flow chart. If neither temperature nor smoke levels are detected, the program flow continues to the check smoke rise rate step at **140**. This requires checking both a level and an elapsed time as will be described later. If the smoke rise rate exceeds a predetermined threshold, which could be affected by the position of the front panel smoke sensitivity control **15**, if used, the routine Fan Run Smoke Differential **142** is executed, followed by the Diverter check **131** which can set the position of an exhaust damper for indoor or outdoor exhaust depending on the level of smoke contained in the exhaust stream. Upon completion it passes control to the Fan Run Smokedown routine **132** as described earlier. If the smoke rise rate is insufficient to trigger a response, the routine moves on to compare the temperature rise rate to a predetermined level **146** which could be affected by the position of the front panel temperature sensitivity control **13**, if used. If a sufficient rise rate is detected at **146**, Fan Run Temp Differential **148** is activated, which passes control on to Fan Run Cooldown **138** upon completion. If neither rates nor levels are exceeded, the program checks the countdown value **152**. If it has not yet run down to zero, it returns to **124**. If it has, then control returns to the beginning of the loop at **122** to be repeated. But before repeating the loop it checks the long term rate of change of the sensor values relative to determine if the guard band levels **154** need to be adjusted. It also checks to see if there is a person present in front of the hood so that it can adjust the volume of an audible alarm **156** accordingly. The next nine flow charts describe embodiments of the individual routines in detail.

FIG. **8** is a flowchart of one embodiment of the Air Quality Monitoring routine **126**. The routine reads the sensors and creates a moving average of each sensor output to provide stability to the software. The routine initializes at **160** and sends a message to the User Interface (UI) display indicating "Monitoring Air Quality" **162**. It sets a loop counter at **164** and reads the temperature sensor at **166** and the smoke sensor at **168**. It accumulates temperature and smoke readings at **180** and **178** respectively, then decrements the loop counter at **170**. At **172** it checks to see if the count has been completed. If it has, it divides the accumulated totals by the number of counts and passes the values for Temperature **174** and Smoke **176** back to the main program, before starting a new loop at **164**. If it hasn't it goes back into the loop and repeats.

FIG. **9** is one embodiment of a routine that sets the guard band levels **154**, in this case for smoke and temperature. The guard bands are used as upper limits for temperature, smoke, etc., in case the rates rise too slowly to be detected by the differential routines. This takes place during idle periods when the fan is not running. If sufficient time has elapsed during which the sensor readings are stable, these become the new background levels, from which the new guard band levels are calculated. The guard band levels are only updated under the conditions that: a) the fan is not currently running, and b) the sensor levels have not changed more than a small incremental value over the prescribed sampling interval which could be on the order of 30 minutes, for example. The routine starts by loading the factory default values **190**. Then it checks to see if the fan is running **192**. If the fan is running, then the routine exits **194**. If not, the routine goes through an evaluation of each sensor. individually. Looking at smoke first, the routine sets a smoke background timer **198**. Then it decrements the timer **202** and reads the smoke level **204**. If the smoke level changed **206**, it goes back to the beginning of the loop **198**. If the smoke level did not change more than the allotted increment, it sets a new temporary background smoke level **208**. It then checks **210** to see if the smoke background timer has elapsed. If it has, which means that the smoke has remained unchanged for the prescribed duration of time, then it established a new background smoke level **230**. Based on this new background level, it establishes new High **214**, Medium **216** and Low **218** smoke guard band levels before returning to the beginning of the loop at **192**.

The temperature guard band is set in exactly the same way. For convenience, it is shown as a parallel operation here, but given the processing speed available today it could very well be done sequentially.

The routine sets a temperature background timer **196**. Then it decrements the timer **200** and reads the temperature level **201**. If the temperature level changed **220**, it goes back to the beginning of the loop **196**. If the temperature level did not change, then, it sets a new temporary background temperature level **222**. Note that not changing means that it changed less than a small prescribed increment. It then checks **226** to see if the temperature background timer has elapsed. If it has, which means that the temperature has remained unchanged for the prescribed duration of time, then it established a new background temperature level **228** Based on this new background level, it establishes new High **232**, Medium **234** and Low **236** temperature guard band levels before returning to the beginning of the loop at **192**.

FIG. **10** shows a flow chart for one embodiment of the Fan Run Temperature Level **136** routine. The routine controls the fan in the case where the guard band levels have been reached. At **240** the routine takes a temperature reading per the monitoring air quality routine described above (FIG. **8**). It checks to see if the High guard band has been reached at **242**. If yes, then it turns on the fan to High speed **244** and writes a message to the UI **245** (if present) indicating that a High temperature level has been detected. Then the routine enters a loop where it checks to see that the fan is maintaining temperature. A timer is set **246**, and the temperature is read **248**. A check is made **250** to see if the temperature is increasing. If it is, the timer is reset **246**, ensuring that the fan will continue running. Otherwise it exits the loop and the timer continues to run. The timer is then read, **252**. If it has not fully elapsed **254** it goes back into the loop at **248**. If the timer has elapsed, it enters the Cooldown cycle **255**, before returning to **240** which is essentially the monitoring mode.

If the temperature is not High **242**, the routine next checks to see if the Medium guard band has been reached at **256**. If yes, then it turns on the fan to Medium speed **258** and writes a message to the UI **259** (if present) indicating that a Medium temperature level has been detected. Then the routine enters a loop where it checks to see that the fan is maintaining temperature. A timer is set **260**, and the temperature is read **262**. A check is made **263** to see if the temperature is increasing. If it is, the timer is reset **260**, ensuring that the fan will continue running. Otherwise it exits the loop and the timer continues to run. The timer is then read, **264**. If it has not fully elapsed **266** it goes back into the loop at **262**. If the timer has elapsed, it enters the Cooldown cycle **138**, before returning to **240**.

If the temperature is not Medium **256**, the routine next checks to see if the Low guard band has been reached at **268**. If yes, then it turns on the fan to Low speed **270** and writes a message to the UI **271** (if present) indicating that a Low temperature level has been detected. Then the routine enters a loop where it checks to see that the fan is maintaining temperature. A timer is set **272**, and the temperature is read **274**. A check is made **276** to see if the temperature is increasing. If it is, the timer is reset **272**, ensuring that the fan will continue running. Otherwise it exits the loop and the timer continues to run. The timer is then read, **278**. If it has not fully elapsed **280** it goes back into the loop at **274**. If the timer has elapsed, it enters the Cooldown cycle **138**, before returning to **240**. If the temperature did not exceeds the Low guard band at **268**, the program flow returns to **240** to repeat the whole process again.

FIG. **11** shows a flow chart for one embodiment of the Fan Run Smoke Level **130** routine. The routine controls the fan and the alarm in the case where the guard band levels have been reached. At **300** the routine takes a smoke level reading per the monitoring air quality routine described above (FIG. **8**). It first checks to see if the smoke alarm level **302** has been reached. If yes, it writes a message to the UI (if present) indicating that a hazardous smoke level has been detected **309**, sets the fan speed to maximum **310**, and activates the audible alarm **312** at the volume level determined by the Alarm Behavior subroutine (FIG. **16**). It then overrides the temperature cycle **314**, reads the smoke level **315** and rechecks to see if the smoke level is decreasing **316**. If it is, it exits the routine. If not, it continues running the fan and the alarm, looping back to read the smoke level **315** until a decrease is detected. If the smoke is not at the alarm level **302**, control passes to **304** where the routine then checks to see if the High guard band level has been reached. If yes, then it writes a message to the UI **317** indicating that a High smoke level has been detected and turns on the fan to High speed **318**. It then overrides the temperature cycle **320**. Then the routine enters a loop where it checks to see that the fan is maintaining smoke level. A timer is set **322**, and the smoke level is read **324**. A check is made **326** to see if the smoke level is increasing. If it is, the timer is reset **322**, ensuring that the fan will continue running. Otherwise it exits the loop and the timer is read **328**. The fan continues to run at High speed until the timer elapses. If it has not fully elapsed **330** it goes back into the loop at **324**. If the timer has elapsed, it enters the Smokedown cycle **132**. If the smoke level is not High **304**, the routine next checks to see if the Medium guard band has been reached at **306**. If yes, then it writes a message to the UI **331** indicating that a Medium smoke level has been detected and turns on the fan to Medium speed **332**. It then overrides the temperature cycle **334**. Then the routine enters a loop where it checks to see that the fan is maintaining smoke level. A timer is set **336**, and the smoke level is read **338**. A check is made **340** to see if the smoke level is increasing. If it is, the timer is reset **336**, ensuring that the fan will continue running. Otherwise it exits the loop and the timer is read **342**. The fan continues to run until the timer elapses. If it has not fully elapsed **344** it goes back into the loop at **338**. If the timer has elapsed, it enters the Smokedown cycle **132**. If the smoke level is not Medium **306**, the routine next checks to see if the Low guard band has been reached at **308**. If yes, then it writes a message to the UI **345** (if present) indicating that a Low smoke level has been detected and turns on the fan to Low speed **346**. It then overrides the temperature cycle **348**. Then the routine enters a loop where it checks to see that the system is maintaining smoke level. A timer is set **350**, and the smoke level is read **352**. A check is made **354** to see if the smoke level is increasing. If it is, the timer is reset **350**, ensuring that the fan will continue running. Otherwise it exits the loop and the timer continues to run. The timer is then read, **356**. If it has not fully elapsed **358** it goes back into the loop at **352**. If the timer has elapsed, it enters the Smokedown cycle **132**. If the smoke level did not exceeds the Low guard band at **308**, the program flow returns to **300** to repeat the whole process again.

FIG. **12** is a flow chart that describes the operation of one embodiment of the Fan Run Temperature Differential routine **148**. This routine, designed for rapid response, controls the fan operation within the temperature guard band levels, in response to detected rates of temperature change. A temperature rate of change corresponds directly to a heat level being given off by the stove, so that the fan speed is set accordingly. Temperature rate detection is an excellent way to quickly detect the onset of cooking.

By looking at the rate of increase rather than a fixed level, this approach greatly reduces the number of false positives. At the same time the guard bands, which are derived from and differentiated from the background conditions, will back up the rate detection scheme in cases where there are gradually increasing changes in temperature that ultimately reach guard band levels.

This rate-detection algorithm could be expanded to incorporate any number of discrete differential intervals (e.g. slow rise, medium rise, fast rise, very fast rise, etc.) with corresponding fan speeds, but for purposes of illustration, two (fast and slow) are included here.

The routine runs in a loop that begins by reading the temperature **370** setting a timer **372** and decrementing the loop counter **374**. The temperature value is checked to see if it has increased enough to constitute a fast rise **376**. If not, it jumps ahead to see is the temperature increase is enough to constitute a slow rise **398**. If the temperature increase is enough to qualify for a fast rise, the timer is then checked **378**, to see how much time has elapsed. If the fast rise interval has already passed, then the routine moves along to **398** to check for slow rise temperature. If the fast rise interval had not elapsed, then the fast rise routine is initiated at **380** by turning the fan on High. A message is also displayed on the UI at **381** saying something along the lines of "Fast Temperature Rise Detected. Fan Speed High." Another counter **382** is started for this routine which will determine how long the fan will stay on. The temperature is read at **384** and checked at **386** to see if it exceeds the Low Temp level. If it does, the routine goes to the Fan Run Temperature Level **136** routine described earlier. If it doesn't, it is checked again at **390** to see if the rise is greater than the prescribed interval DeltaT. If it is, the routine goes back into the loop, keeping the fan running, decrementing the counter at **382**. If not, it continues to decrement the counter **392**. The counter value is checked at **394**. If it has elapsed, control is then passed to the CoolDown routine **396** which will bring the fan speed gradually down to zero. If it hasn't elapsed yet, it goes back into the loop with the fan still running at **384** where the temperature is checked again.

If the temperature at **398** was less than the Slow rise temperature control returns to the beginning of the loop at **370**. If the temperature exceeds that threshold the routine goes on to check the elapsed time interval at **400**. If the slow rise time interval has already elapsed, control returns to the start **370** which is, in essence, returning to the Main program. On the other hand, if the Slow rise counter has not yet elapsed **400**, the routine enters the Slow differential routine at **402** by turning the fan on at Medium speed. A message is also displayed at on the UI at **404** saying something along the lines of "Slow Temperature Rise Detected. Fan Speed Medium." Another counter **406** is started for this routine which will determine how long the fan will stay on. The temperature is read at **408** and checked at **410** to see if it exceeds the Low Temp level. If it does, the routine goes to the Fan Run Temperature Level **136** routine described earlier. If it doesn't, it is checked again at **414** to see if the rise is greater than the prescribed interval DeltaT. If it is, the routine goes back into the loop, decrementing the counter at **406**. If not, it continues to decrement the counter **416**. The counter value is checked at **418**. If it has elapsed, control is then passed to the CoolDown routine **396**. If it hasn't elapsed yet, it goes back into the loop with the fan still running at **408** where the temperature is checked again.

FIG. **13** is a flow chart that describes the operation of one embodiment of the Fan Run Smoke Differential routine **142**. This routine, designed for rapid response, controls the fan operation within the Smoke guard band levels, in response to detected rates of Smoke level change. The operation is quite similar to the Temperature Differential routine described above (FIG. **12**), although in this case, although any number of discrete differential rates could be used with corresponding fan speeds, only one differential level is shown. The first loop begins by starting a smoke differential counter **430** and then reading the smoke level **432** before decrementing the counter **434**. At **436** it checks to see if the smoke level has increased beyond a predetermined increment. If not, it loops back for another smoke level reading **432**, but not before checking **440** to see if the smoke has exceeded the Low Smoke (guard band) level. If yes, it calls the Fan Run Smoke Level routine **130**. If, at **436**, the smoke has exceeded the smoke differential increment, it checks the counter value at **438** to see if the second condition has been met for a rate of change sufficient to warrant a response. If the counter value exceeds the predetermined interval **446** it reenters the loop, checking at **442**, if the loop counter has elapsed. If yes, it returns to **430** to start a new loop, otherwise it continues the existing loop at **432**. On the other hand, if the count at **446** was within the predetermined interval, meaning that the rate of increase was of concern, fan operation is initiated **448** at a Medium speed. This overrides the temperature cycles by priority **450**, and starts a fan run counter **452** to determine how long, in an open loop manner the fan will stay on. The smoke sensor is then read **454** to supplement the open loop control with a closed loop component. First, the smoke level is checked to see if it exceeds the Low smoke level threshold **456**. If yes, then control is passed to the Fan Run Smoke Level routine **130** described earlier. If not, the smoke increase is then compared with a preset increment delta S **458** to see if the smoke level is increasing significantly. If it is, control is passed back into the loop at **452**, which resets the counter, keeping the fan running for another cycle. If the smoke level is not increasing, the counter is decremented **462** reducing the remaining run time. If the counter has fully elapsed **464**, control is passed to the Smokedown routine **132**. Otherwise it returns into the loop to read the smoke sensor again 454.

FIG. **14** describes the CoolDown Cycle **138** which is called after a Fan Run Temperature Level **136** or Fan Run Temperature Differential cycle **148** has completed. This means that the fan has been running for some minimum period of time. The reason for this cycle is that with the fan running, it is difficult to tell what is happening on the stove below, since the ventilation tends to drive the detected temperature or contaminant level down to the ambient level. At this point there is a substantial loss of sensitivity to any rate of effluent emission that is less than the amount being evacuated. If, in order to improve sensitivity, the fan is turned off to resample the air, and then immediately turned back on again when heat or effluents are present, this could result in unstable or jerky operation that could prove objectionable to the user, particularly from a noise standpoint. The Cooldown routine seeks to balance the amount of air being exhausted with the amount of heat being generated by gradually reducing fan speed when continuously checking the temperature to make sure that the heat is off and the temperature is decreasing. Decreasing fan speed, essentially increases the sensitivity of the system. If it senses a temperature rise rate or level sufficient to trigger one of the routines described earlier, it will return to the appropriate cycle. If there is no change in temperature, the Cooldown will continue to cycle and run the fan at low speed, incrementally reducing the speed until, seeing no further temperature rise, finally shuts the fan off. This indicates that the system has returned to equilibrium and is returned to the standby/sampling air quality mode.

The cycle initializes at **470** then sets a loop counter **472** and setting the fan to a preset speed **474**, which is generally close to the speed at which it initially enters. It then enters the inner countdown loop **476** by decrementing the counter. It checks **478** to see if the counter is exhausted. If it is, the fan is shut off **484** and the routine is exited **486**. If not, the loop continues by decreasing the fan speed at a preset reduction increment **480**. In this embodiment there are two reduction rates that are used: Fast and Slow. The cycle begins with the Fast reduction rate by default which utilizes a larger speed reduction increment. At this point the temperature is read **482** and then checked **488** to see if there was an increase. If there was no increase, control passes back to the beginning of the loop, decrementing the counter **476** thereby reducing the remaining run time. If the temperature did show an increase, control passes to **490** where the elapsed count is checked. In either case, control will return to the initial outer loop entry point **472**, which resets the fan run time counter, keeping the fan running. If it was early in the count (e.g. less than halfway) that indicates that the temperature rise came quickly. Therefore the fan speed is set, in this case to medium **492** and the reduction rate set at fast **494**. In this way the controller is searching for the fan speed that balances the amount of heat being exhausted through the fan vent with the amount being produced by the stove. This path could be considered a search of coarse granularity. On the other hand, if the temperature rise had been detected later in the count (e.g. gone past halfway in this embodiment), that means the temperature was rising more slowly, the controller moves to the path of finer granularity, where the speed is set to Low **496** and the reduction rate is set to Slow **498**. The speeds and rates described above should be considered exemplary for this one particular embodiment, though it should be understood that other speeds and rates could also be used.

FIG. **15** refers to one embodiment of the SmokeDown cycle **132** which serves a similar function to the CoolDown **138**, except that it is utilized in the case where the system had been responding to smoke or gas. It is called after a Smoke Level **130** or Smoke Differential **142** cycle has completed, which means the fan is still running. It gradually reduces fan speed when continuously checking the smoke level to make sure that the heat is off and the smoke level is decreasing. If it senses a smoke level rise or preset level, it will return to the appropriate cycle. If there is no change in smoke level, the Smokedown will continue to cycle and run the fan at low speed until it sees no further smoke level rise. This indicates that the system has returned to equilibrium and the fan is then shut off. The cycle initializes at **500** then sets a loop counter **502** and setting the fan to a preset speed **504**, which is generally close to the speed it initially enters at. It then enters the inner countdown loop by decrementing the counter **506**. It checks **508** to see if the counter is exhausted. If it is, the fan is shut off **510** and the routine is exited **512**. If not, the smoke level is read **514**. If the smoke level is greater than the guard band level **516**, the controller exits Smokedown **518** and moves into Run Smoke Level **528** that was described previously (FIG. **11**). If the level did not exceed the guardband level **516**, the rate is then checked to see if the Differential Rate Level is exceeded **520**. If yes, controller exits Smokedown **524** and moves into Run Smoke Differential **142** that was described previously (FIG. **13**). If the rate did not increase, the level is then checked to see if it increased at all **522**. If not, the counter is decremented **506** and the loop repeated until the counter runs down **508** and the fan turns off **510**. If the smoke level did increase at **522**, control returns to **502** to start a new cycle and keep the fan running.

FIG. **16** describes one embodiment of the Set Smart Alarm Behavior routine **156**. This routine, adjusts the volume of the audible alarm depending on how recently the motion detector was activated. The idea behind this is that if a person is nearby the alarm does not need to be very loud. This is intended to avoid having this safety feature becoming an annoyance. Upon initialization, the alarm volume is set to High **540**. The motion sensor is monitored **542** in a continuous loop which is exited if the presence of a person is detected **544**. Once a person is detected the alarm volume level is set to Low **546**. At that point an interval counter is set **548**. At each interval, the volume is increased **560**. If a person is detected **562** control returns to **546** where the volume is reduced and the counter is restarted **548**. Otherwise, the counter is decremented **564**. If the counter has fully elapsed **566**, with sufficient counts to have brought the volume back to the High level, control returns to the beginning of the sequence **540**. Otherwise, the routine returns to **560** where the alarm volume is increased.

FIG. **17** shows the actual performance of one embodiment of the range hood controller in a test run of about 15 minutes in duration where water was boiled in a pot on the stove beneath the hood. There are two variables being plotted as a function of time; **701** shows the output of the temperature sensor (solid line), while 702 shows the fan speed (dashed line).

At time T=0, the heat is turned on under the pot. The fan is OFF (0 rpm). The temperature rises gradually until the water begins to boil at **703**, at which point it rises quickly. Detecting the rapid rise, the controller turns the fan ON to 2200 rpm at **704**. As soon as the fan reaches speed, the temperature drops as a result. The temperature is now under control. Seeing that the temperature has dropped at **705**, the fan speed is then reduced to 1500 rpm at **706**. Once the fan speed drops, since the water is still boiling, the temperature shoots up again at **707**. Seeing this rise, the controller increases the fan speed to 2300 at **708** which drives the temperature down to 67° at **709**. Seeing this the fan speed is reduced and the temperature begins to rise again. Notice that all the while, the temperature under the hood is being maintained within a 3-4 degree range. At **710**, the temperature rise triggers another fan increase at **711**. At **712**, the heat under the water is turned OFF, though the water continues to boil briefly. At **713**, which is 600 seconds into the run, the controller goes into the "cooldown" mode because the temperature is no longer rising rapidly, which means the amount of heat coming from the stove is reduced. This mode allows the fan speed to continue dropping as long as the heat that is being exhausted by the fan exceeds the heat emitted by the stove. At **714**, the speed drops all the way to 1230 rpm before it senses a heat rise. Fan speed is then increased again at **715**, but only briefly as the controller continues to "search" and "locate" the heat level coming off the stove, based on the rate of temperature increase. Finally, at **716**, sensing a "flattening out" of the heat rate, it continues to reduce the fan speed, incrementally, until it shuts off at **717**. Thus, we have a controller that has the capability of monitoring an air quality parameter such as temperature and maintaining a ventilation rate sufficient to maintain temperature within a tight range while heat is being produced, and is then able to detect when the heat has stopped and shut itself off automatically. It is also capable of far smoother operation than any system that simply turns ON and OFF at prescribed temperature levels. Because it looks at heat rate, as well as the temperature, it is not affected by the ambient temperature in the installed location. Note that the fan stays ON throughout the entire incident, though the speed is modulated in response to the changing environment.

FIG. **18** shows the performance of one embodiment of the hood in the case of smoking food. This time history shows the Temperature **805**, Smoke level **820** and fan speed (rpm) **801** over a five minute interval beginning with smoking food being introduced beneath the hood for two minutes. After 16 seconds the smoke is detected as a peak of 100 units **800** which switches the fan on based on a differential rise in smoke level. Eight seconds later the fan is running at 2300 rpm **802**. At this point the algorithm drives the fan at this level for 90 seconds while checking to see that the smoke remains with upper and lower limits. If the controller detects a certain level of smoke activity, it will reset the countdown timer so that it will run another 90 seconds. Otherwise, it will go into the cooldown mode. Since in this case there has been some increasing movement of the smoke level between points **804** and **808**, the controller allowed the fan to continue running at **810**. The smoke source begins to taper off at **812**. In the second cycle, the controller saw a decrease in smoke level between **814** and **816**, so it went into the cooldown cycle at **818**. As the smoke level continued to drop, the controller continued to reduce the fan speed until it finally turned off just after 300 seconds. Since the heat rate was low, we saw modest temperature rise to a peak of 85 at **806**. This was the point at which the heat balance tipped in favor of the heat being extracted exceeding the amount of heat being emitted, so that the temperature declined throughout the rest of the run, ending up at 69 degrees, which was close to ambient.

FIG. **19** shows the operation of the Diverter Check routine. This is an energy conserving option that diverts the exhaust airflow from indoor to outdoor depending on the degree of contamination, By keeping the exhaust indoors except in cases of high contamination, energy, in the form of heated or cooled air is conserved. It is illustrated here in conjunction with the smoke sensor, but the operation could also be tied to any sensor, for example, CO, temperature, humidity, a combination, etc. At **900** the smoke sensor is read. If the level is found **902** to exceed the diverter level threshold, meaning that outdoor ventilation is required, a message indicating this action is sent to the user interface **904** and the diverter is activated **906**. Control is returned to **900** and the loop is repeated. If the smoke level is below the diverter threshold **902**, then the diverter is closed **908**. The diverter can be opened and closed with any of a number of mechanisms including a solenoid and a spring, a linear actuator, increased airflow, etc.

FIG. **20** shows a front panel selector switch to be used with the energy saving flow diverter feature. Rotary knob **920** is used to select between the three exhaust flow options: Indoor **922**, Outdoor **924**, and Auto **926**. In the Auto mode, the diverter check routine described above (FIG. **19**) is used. Otherwise the flow is directed indoors or outdoors as selected. In this embodiment, an electrical actuator such as a solenoid would be used to open and close a flow damper. An alternative embodiment might use a mechanical device, such as a weighted damper that could open at or above a certain flow level.

With a software-based control system there are innumerable variations that can be implemented in terms of settings, timings and control responses. The control software programming technique can also be varied to include such approaches as fuzzy logic control, neural networks, proportional, differential, integral (PDI) control, etc. The number and types of trigger levels and rate detection schemes can also be varied. Alternative air quality sensors have already been mentioned. FIG. **3** shows a configuration with an external control module that could potentially be configured as an aftermarket add-on to an existing range hood. An additional configuration could include an alarm reset that kills the audible alarm and a fan reset that will quickly turn off the fan without the need to go into manual mode.

While the disclosed subject matter has been described with respect to a limited number of embodiments, the specific features of one embodiment should not be attributed to other embodiments of the disclosed subject matter. No single embodiment is representative of all aspects of the disclosed subject matter. Moreover, variations and modifications therefrom exist. For example, the disclosed subject matter described herein may comprise other components. Various additives may also be used to further enhance one or more properties. In some embodiments, the disclosed subject matter is substantially free of any additive not specifically enumerated herein. Some embodiments of the disclosed subject matter described herein consist of or consist essentially of the enumerated components. In addition, some embodiments of the methods described herein consist of or consist essentially of the enumerated steps. The claims intend to cover all such variations and modifications as falling within the scope of the disclosed subject matter.

What is claimed is:

1. A method for automatic control of range ventilation, designed to balance the objectives of maintaining air quality, reducing unnecessary loss of conditioned air and minimizing objectionable noise; the method comprising: configuring one or more sensors to sense one or more hazards generated in the operation of a residential cooking appliance; and communicate with a processor that executes an event detection program that, sensing information related to the one or more hazards by reading the sensor data with fan or fans off or at a predetermined minimal sampling air volume, and evaluating said data with respect to either set threshold levels or multiple sampling intervals of varying length, is able to detect the occurrence of a stove-related event such as a gas leak or the onset of cooking; and classify the event into one of several behavioral categories such as: threshold-exceeding, gradually-changing and rapidly-changing; wherein the step of determining a gradually or rapidly-changing category related to one or more hazards comprises monitoring any one or more parameters over one or more specified time intervals to see if the parameter reading has changed by a specified minimum amount during said interval; wherein the algorithm watches each parameter for X seconds, looking, as an example, for a rise of Y degrees, or Z % contamination, to determine a rate of change **R1**, wherein **R1** might be gradual, **R2** moderate, **R3** rapid and so forth; these rates can then be communicated to a user or used to adjust response program parameters.

2. The method of claim **1**, wherein the-step of determining the sensitivity of response Includes: reading a user-selected control setting adjusting the duration of sampling intervals during which the program looks for a sensed parameter change; thus, a user more concerned with safety can set the sensitivity high, while a user more concerned with reducing noise and energy use can set it lower.

3. The method of claim **1**, wherein the step of determining a threshold-exceeded category comprises comparing sensor readings related to the one or more hazards to threshold levels that are adjusted relative to the ambient environmental conditions; the algorithm monitors ambient conditions around the clock, searching for a stable periods of at least T minutes to be used as a reference for the next time the algorithm is utilized; when run, the algorithm uses the most recent stable period as reference; once an event has been detected, calibration is locked until the event is cleared.

4. The method of claim **1**, wherein the program provides the energy-saving option to direct exhaust indoors except when the sensors indicate the presence of potentially harmful effluents in which case the controller automatically opens a damper capable of diverting exhaust outside.

5. A method for automatic control of range ventilation designed to balance the objectives of maintaining air quality, reducing energy loss, and minimizing objectionable noise, incorporating: sensors to detect one or more air quality effects generated in the operation of a cooking appliance; and communicate with a processor that executes an event response program that oversees the response to a detected event including deployment of one or more alarms and control of the fan or fans to deliver ventilation airflow appropriate to a determined category comprising the following steps:

programmatically reducing the speed of at least one of the one or more fans; repeating the step of sensing information related to the one or more hazards via the sensors; to determine whether the event is unchanged, if it should be reclassified or if it has concluded, and controlling the one or more fans or alarms based on the appropriate response; wherein when periodic air sampling under controlled air flow reduction determines that the event has not concluded, the program returns to its entry point; when the event is determined to have concluded, the airflow is reduced to the initial condition, either off or at some sampling volume, and then the program terminates.

6. The method of claim **5** where the user can control the desired system behavior by specifying the intensity of response which adjusts variables that control fan speed associated with each category.

7. The method of claim **5** where the user can select the desired system behavior by specifying the duration of response which adjusts variables that determine when the event is considered to have concluded; this will impact the overall rate at which the fan speed will be reduced, in order to allow sensors to “listen” to the environmental factors.

8. A system for automatically controlling range ventilation designed to balance the objectives of maintaining air quality, reducing energy loss, and minimizing objectionable noise, the system comprising: sensors to detect one or more air quality effects generated in the operation of a cooking appliance; a processor that executes a control program with two distinct phases;

the first being a monitoring program that, by reading the sensor data with fan or fans off or at a predetermined minimal sampling air volume, and evaluating said data with respect to set threshold levels or sampling intervals for detecting rate of change, is able to detect the occurrence of a stove-related event such as a gas leak or the onset of cooking; and then classify the event into one of several behavioral categories such as: threshold-exceeded, gradually-changing and rapidly-changing;

the second, being a response program, takes over when an event has been detected, that oversees the response to said event including deployment of one or more alarms and control of the fan or fans to deliver ventilation airflow appropriate to the determined category, while programmatically reducing airflow in a controlled manner to enable periodic air sampling, while still ventilating, to determine whether the event is unchanged, if it should be reclassified and the response updated, or if it has concluded.

9. The system of claim **8**, further comprising a control capable of accepting a user-selected input to adjust system behavior, wherein said control adjusts the duration of sampling intervals during which the program looks for a sensed parameter change, thus allowing a user more concerned with safety to set the sensitivity high, while a user more concerned with reducing noise and energy use can set it lower.

10. The system of claim **8**, further comprising one or more additional sensors, wherein said one or more additional sensors are capable of sampling ambient elements related to the one or more hazards around the clock, searching for a stable periods of at least T minutes to determine a set of background conditions to be used as a reference for the next time the algorithm is utilized; when run, the algorithm uses the most recent stable period as reference; a threshold-exceeded category is determined by comparing sensor readings to threshold levels that are adjusted relative to said ambient reference levels; once an event has been detected, this calibration process is locked until the event is cleared.

11. The system of claim **8**, where a gradually or rapidly-changing category is determined by monitoring any one or more parameters over one or more specified time intervals to see if the parameter reading has changed by a specified minimum amount, during said interval the algorithm watches each parameter for X seconds, looking, as an example, for a rise of Y degrees, or Z % contamination, to determine the rate of change **R1**, where **R1** might be gradual, R**2** moderate, R**3** rapid and so forth; these rates can then be communicated to user and to adjust response program parameters.

12. The system of claim **8**, further comprising a notification system capable of providing a notification, wherein said notification system comprises a user interface, colored lights, an alphanumeric display, an electronic remote messaging component, and/or an audible alarm.

13. The system of claim **12**, further comprising a proximity unit capable of judging the proximity of the user, wherein the notification is adjusted based on the proximity of the user.

14. The system of claim **8**, wherein the program provides the energy-saving option to direct exhaust indoors except when the sensors indicate the presence of potentially harmful effluents in which case the controller automatically activates a damper capable of diverting exhaust inside and outside to ensure that exhaust is directed outside.

15. The system of claim **8** where if periodic air sampling under controlled air flow reduction in phase **2** (the response program) determines that the event has not concluded, the program remains in phase **2**; if the category of event has changed, the response is updated commensurate with the category; if the event is determined to have concluded, the airflow is reduced to the initial condition and control is returned to the first phase.

16. The system of claim **8** where the user can control the desired system behavior by specifying the intensity of response which adjusts variables that control fan speed associated with each category.

17. The system of claim **8** where the user can select the desired system behavior by specifying the duration of response which adjusts variables that determine when the event is considered to have concluded; this will impact the overall rate at which the fan speed will be reduced, in order to allow sensors to “listen” to the environmental factors.

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